BIOLOGY 30 STUDY GUIDE

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Holy Trinity Academy

Veritas: Christo et ecclesiae

BIOLOGY 30

UNIT 1

SYSTEMS REGULATING CHANGE IN HUMAN ORGANISMS

1. The human organism regulates physiological processes, using electrochemical control systems.

- ***the human organism, like other organisms, maintains control over its internal environment with neural systems, by extending from Science 10, Unit 1, energy systems, Science 10, Unit 2, cell processes and Biology 20, Unit 4, the biological systems that maintain the organism's equilibrium with the environment, and by:***
- ***describing the structure and function of a neuron and myelin sheath, explaining the formation and transmission of an action potential and the transmission of a signal across a synapse or neuromuscular junction and the main chemicals and transmitters involved; i.e., norepinephrine, acetylcholine and the enzyme that breaks them down.*** pp 366-372

Introduction

Nervous control of body functions involves reception, transmission, interpretation and response. All of this is coordinated by the brain and the spinal cord which are collectively called the central nervous system, or CNS, and body nerves in the peripheral nervous system (PNS) and autonomic nervous system (ANS).

The organization of the Nervous System is presented in diagram 1.

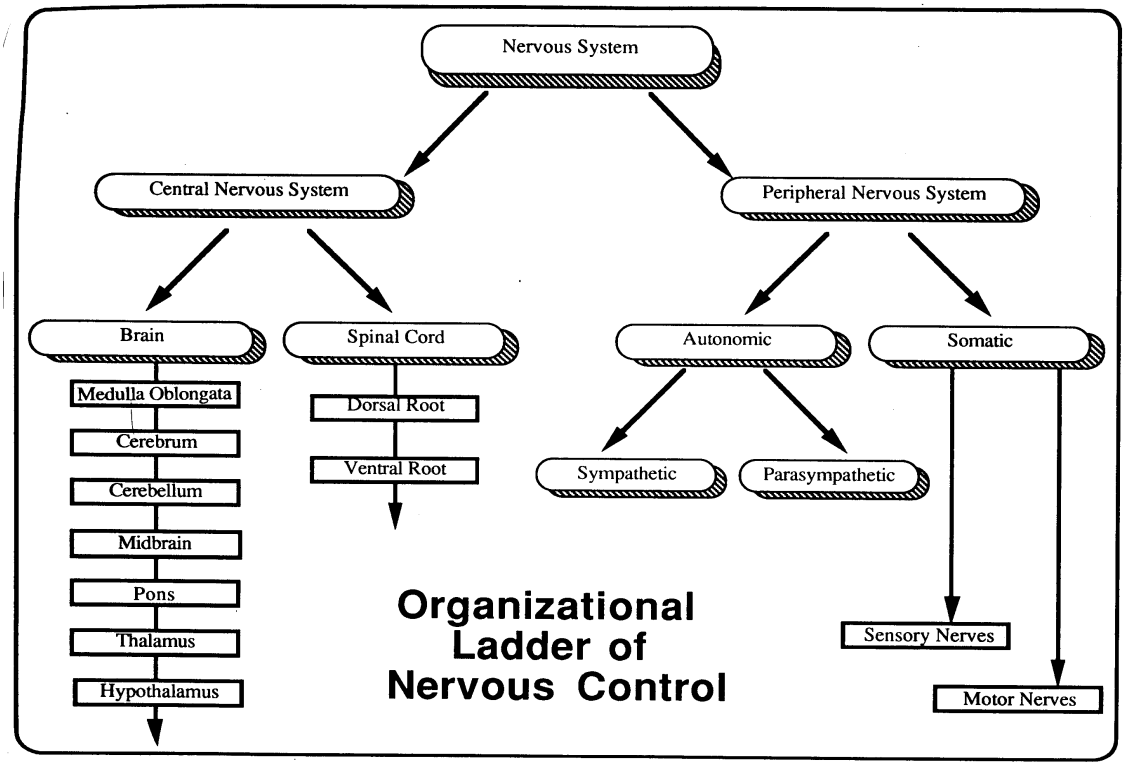


Diagram 1: The organization of the nervous system

(Aug 2006: MC 1,2)

I)The parts of the neuron: refer to diagram 2 of all parts listed below.
Neurons are the structural and functional units that compose all parts of the nervous system. They are cells with cell membranes that produce an electrical impulse. Nerves are made of 1000's of neurons.
There are three types of neurons:
1.Sensory Neurons carry a nerve impulse away from the receptors to the spinal cord or directly to the brain.
2.Motor Neurons carry a nerve impulse away from the brain to the muscles or glands.
3.Association Neurons carry nerve impulses across the spinal cord and to the brain. These are found only in the CNS and are much shorter and slower than sensory or motor neurons, and are unmyelinated.
Neurons are made of a cell body, a long axon, and a dendrite. Most neurons can send impulses as fast as 200 times/sec, travelling at about 400 km/h. Nerves communicate with other nerves or with other cells by passing a chemical message through a special structure at the end of the axon called a synapse.

(January 2001: M.C. 3,5,6, June 2002: MC 1)

a) The Axon: An axon is one long cell extension that conducts the nerve impulse away from the nerve cell's body. Some axons in the human body can be over a meter long. The axons of nerves outside of the CNS are coated with a fatty protein sheath that is whitish in color and is called myelin.
b) Myelin: This material insulates the axon much like the plastic coating on electrical wire; it does not provide protection. Sometimes called the myelin sheath. The inner areas of the spinal cord and the outer area of the brain are nonmyelinated. The complete PNS is myelinated.
c) Schwann cell: Are individual cells that surround the axon and produce myelin. This wrapping insulates large portions of an axon and allows these portions of the axon to be quickly passed over during nerve transmission.
d) Nodes of Ranvier. Gaps between the myelin wrappings (schwann cells) on the myelinated axon. Nerve transmission occurs at the node only and skips over the insulated portion of the axon. This allows the nerve impulse to propagate or move along on the myelinated neuron as the current jumps from node to node. As a result of this design myelinated nerves are 50 times faster than unmyelinated nerves.
e) The Dendrite: Dendrites are several shorter branched extensions of the cell body that receive incoming signals and deliver them to the cell body. Some neurons may have up to 4000 dendrites.
f) The Cell body: Dendrites deliver a nerve impulse (signal) to a cell body of the neuron. The impulse spreads over the cell body and then moves away through the axon.
g) The Neurilemma: The neurilemma is a delicate membrane around the axon which promotes regeneration of a damaged neuron. It is only found on myelinated neurons (white matter); unmyelinated neurons (grey matter) are not repairable. The neurilemma, along with the myelin sheath work together to regenerate damaged nerves.

Myelinated neurons	Unmyelinated neurons
White matter: has fat/myelin/schwann cells	Gray matter: no fat/myelin/schwann cells
In PNS and CNS	Only in CNS
Can repair damage: has a neurilemma	Cannot repair damage: does not have a neurilemma
Impulse travels faster	Impulse travels slower

(January 2002: M.C. 7,8)

e) The Synapse: see diagram 3
The synapse is the process of movement of the impulse from the axon of one neuron to the dendrite of another neuron or membrane of a gland or muscle. A synaptic cleft is a junction between the axon of one neuron (presynaptic neuron) and the dendrite of another neuron (postsynaptic neuron). On the axon side there is a synaptic knob, a swelling of the end of an axon, which contains synaptic vesicles. These vesicles are tiny vacuoles which contain chemicals (acetylcholine) that act as neurotransmitters which are released into the gap or junction. These neurotransmitters will excite or inhibit the neighboring neurons by attaching to receptor sites on the membrane of the dendrite or effector the nerve is going to. Excitatory synapses cause depolarization of the next neuron while inhibitory synapses prevent depolarization of the next neuron. The postsynaptic membrane releases cholinesterase that breaks down acetylcholine clearing the synapse and preventing further impulses.
(I.B. only. The arrival of the impulse at the axon end plate causes and influx of calcium ions. This influx causes vesicles to fuse with the membrane releasing Ach into the synaptic cleft.)

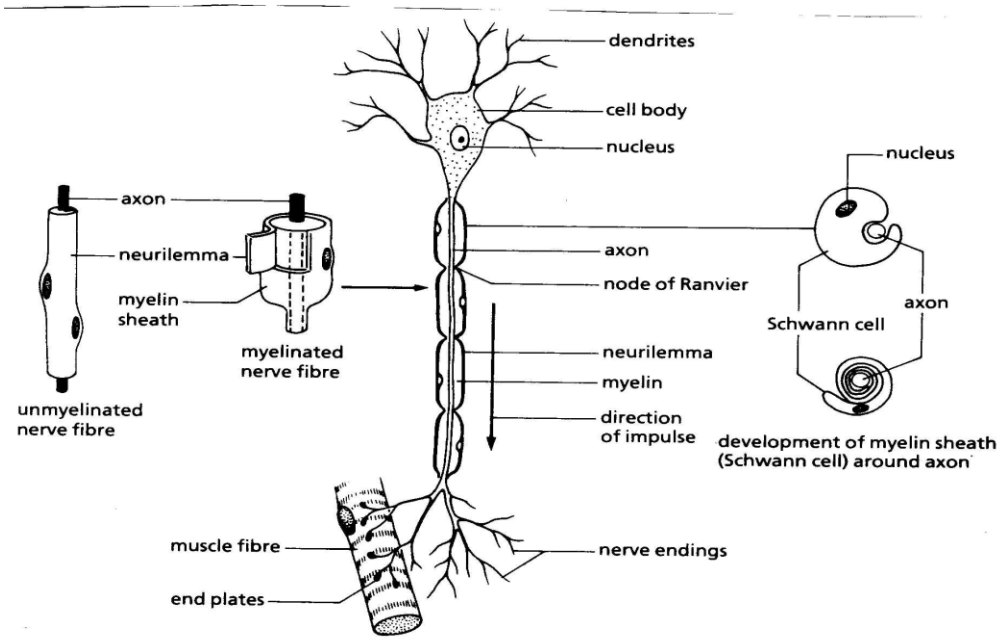


Diagram 2: The anatomy of the neuron
(June 2005: MC5)

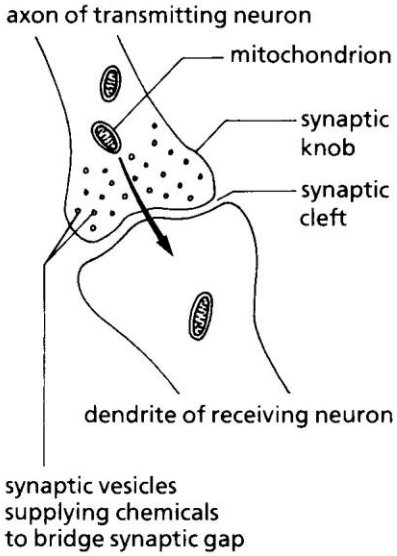


Diagram 3: The synapse

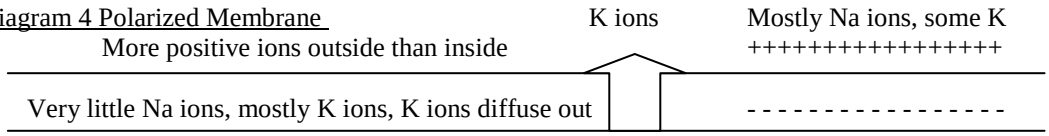
f) Nerve:
A bundle of myelinated axon fibers found outside the CNS.

II)Nerve Impulse Transmission: (pp. 372-382)
Electricity travels faster than nerve impulses, electric current decreases with distance while impulse strength does not, electricity has an external source of energy while impulses have an internal cellular source of energy, electricity is the movement of electrons through a conductor while impulses are the movement of ions across a membrane.
The cell membrane of the neuron is the structure that allows the neuron to function as a cell able to transmit a nerve impulse. In order to understand nerve impulse transmission it is important to understand the activity of the membrane before the impulse begins.

a) Resting Membrane (Membrane Potential) Polarized neuron-at rest before it is stimulated (see diagram 4)

1. Fluid is found both inside and outside the neuron. There are K ,Na, and Cl ions in the fluids.
2. There are tiny channels with gates along the neuron membrane that control the movement of Na and K ions across the membrane
3. There is a difference between the charge (ion concentration) outside the cell compared to inside the cell. This is called the membrane potential. This potential is achieved by the active transport of Na ions out of the cell by the Na/K pump, found inside the neuron membrane. This pump transports out 3 Na for every 2 K that it transports in. In addition, the Na gates are closed preventing Na from diffusing back in, and the K gates are open allowing K to diffuse back out. Thus a relatively negative inside is created because the negative Cl remains unchanged inside.
4. This creates high concentrations of Na and low K outside the cells membrane, and low Na and high K inside the cell.
5. The result is a positive charge outside the membrane and a negative charge inside.

Diagram 4 Polarized Membrane

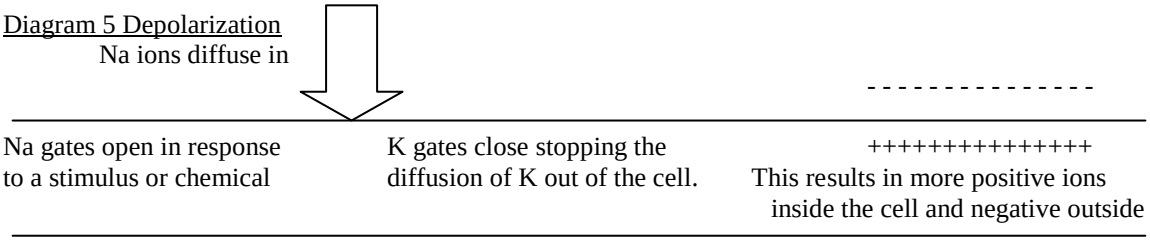


b) Nerve impulse, (Action Potential), Depolarization (see diagram 5)

This is the pulse-like change in membrane potential. This is needed to transmit impulses through the nerves. It results from the rapid change in membrane permeability to Na.

1. Certain chemicals (neurotransmitters) produced by the body, or external stimuli, stimulate the membrane of the dendrite.
2. This membrane becomes 5000 times more permeable to Na (Na gates open)
3. Na rushes in by diffusion
4. There is a sudden loss of the normal negative charge inside the nerve cell, it becomes positive
5. This charge reversal is the actual impulse/signal, and causes the membrane to become less permeable to Na (Na gates close)

Diagram 5 Depolarization

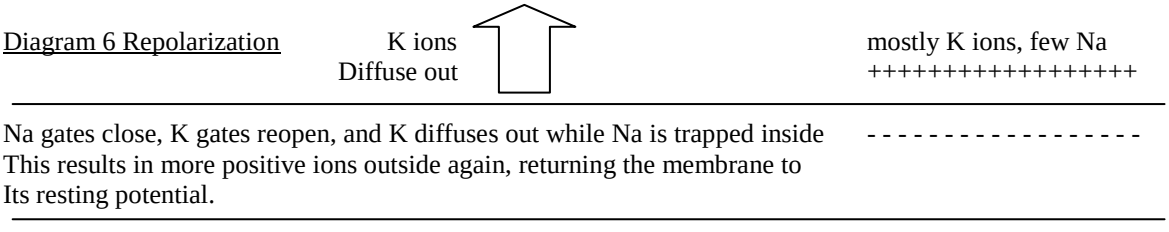


c) Refractory Period (Repolarization) see diagram 6

This is the time when the neuron is returned to its normal resting potential.

1. Repolarization occurs almost immediately after the membrane closes its gates to Na
2. The membrane becomes more permeable to K (K gates open)
3. K will rush out because there is a high concentration of K inside the cell and a low concentration outside the cell.
4. The normal negative charge inside the cell is restored, but Na and K are on the reverse sides.
5. The Na/K pump moves 3 Na out for every 2 K moved in restoring the membrane back to resting state.

Diagram 6 Repolarization



	Na gate	K gate	Na/K pump	Ion diffusion	Memb. charge
Polarized	Closed	Open	Na out/K in	K out	+out/- in
Depolarized	Open	Closed	Na out/K in	Na in	+in/-out
repolarized	Closed	Open	Na out/K in	K out	+out/-in

(June 2000: M.C. 5,6) (June 1999: M.C. 4,5) (June 2002 MC 42)

d) Propagation of the Action Potential
Once the action potential occurs at one spot it excites an adjacent portion of the membrane (causes the Na gates to open) to become more permeable to Na and so on down the entire length of the neuron.

e) Impulse Characteristics
- once and impulse is started it can't be stopped
- impulses travel at 1 to 120 m/s
- a nerve can be made of 100's of neurons
- inside a neuron impulses always move in one direction: dendrite→ cell body → axon
- between two separate neurons impulses move from the axon (end plate) of one neuron to the dendrite of the next neuron

(June 2005 MC: 3 NR 2)

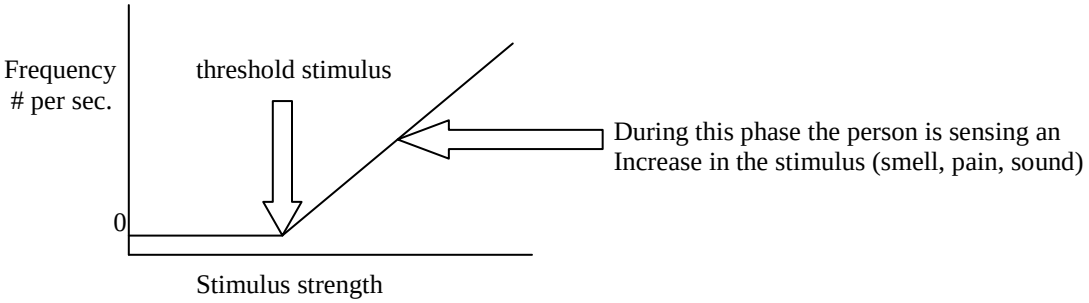
f) Principle of Nerve Impulse Transmission
Threshold Levels (see diagram 7)
A minimum stimulus (chemical, electrical, light, sound, other) that makes the neuron membrane permeable to sodium, to cause depolarization, is the threshold value of that neuron. Different neurons in the same person and the same neuron in different people can have different threshold values. This, in part, explains the differences in tolerance or sensitivity different people have to the same stimulus (pain, smell).

Diagram 7- illustrating a 3mV threshold stimulus (or threshold value)

Stimulus strength	Impulse voltage
1mV	-70 mV
2mV	-70 mV
3mV	+20 mV
4mV	+20 mV
5mV	+20 mV

All or None Response
An individual impulse will not vary in size or strength, it either occurs or it does not, the membrane is totally depolarized or does not at all (see diagram 7). Once the action potential has been stimulated at one spot on the nerve membrane, the action potential will spread over the entire neuron. The stronger the stimulus is the greater the frequency of impulses produced by that neuron (see diagram 8).

Diagram 8: stimulus strength versus frequency of impulses



Neurotransmitters (see diagram 3)
Are chemicals that are produced by the axon end plate of the presynaptic neuron and cause depolarization (cause the membrane to become permeable to sodium) of the dendrite of the postsynaptic neuron. The most common neurotransmitter in the body is acetylcholine. Other examples of neurotransmitters include adrenaline/noradrenaline (also called epinephrine and norepinephrine), and many psychoactive drugs—LSD, Psilocybin These are produced in the synaptic vesicles and are secreted into the synapse (synaptic cleft) when the impulse arrives at the axon end plate. Once depolarization happens an enzyme called cholinesterase (short for acetylcholinesterase) is released from the dendrite, which breaks down acetylcholine preventing continuous depolarization of the postsynaptic neuron (resulting in paralysis or a muscle cramp).

Excitatory transmitters/synapses: Cause the postsynaptic neuron to depolarize, continuing the impulse from one neuron to the next

Inhibitory transmitters/synapses: Prevent the postsynaptic neuron from being able to depolarize. This prevents the impulse from being transmitted to the next neuron. It is believed that many inhibitory chemicals make the postsynaptic membrane more permeable to potassium. By opening more potassium gates, the potassium ions on the inside of the neuron follow the concentration gradient and diffuse out of the neuron. The rush of potassium out of the cell increase the number of positive inns on the outside of the cell relative to the number found on the inside of the cell. Such neurons are said to be hyperpolarized because the resting membrane in even more negative. More sodium channels must now be opened to achieve depolarization and a action potential.

Summation: the effect produced by the accumulation of transmitter chemicals from two or more neurons. Whether or not a postsynaptic neuron will fire depends on the effects of more than one presynaptic neuron. The presynaptic neurons can be stimulatory or inhibitory.
Stimulation of a sensory neuron produces an action potential. An abnormal pattern in this action potential can be used to detect MS in its early stages.

(January 1999: M.C. 1) (June 2002 MC:3 June 2005 MC 4)

• ***describing the composition and function of a simple reflex arc and the organization of neurons into nerves*** page 370

There are two types of nerve pathways: 1. A learned response and 2. a reflex arc.
Learned Response:
A conditioned response is one in which information from the environment goes to the brain, is processed, and the brain decides what action to take. We have conscious control over this.
The Reflex Arc: see diagram 9
The spinal cord, not the brain, is the organ of the nervous system responsible for reflexes. Reflexes are quick involuntary, not learned, responses or actions that the body takes to protect itself from danger. The reflex arc is the pathway that the nerve impulse follows when a stimulus occurs. This pathway begins with a sensory organ detecting a dangerous stimulus. Then an impulse is passed from the sensory organ to a sensory neuron. The sensory neuron takes the message to the spinal cord where it is picked up by an association neuron (interneuron). The interneuron passes the message immediately to the appropriate motor neurons. The motor neuron takes the message to the effectors that can do something to bring about a change to whatever is causing the stimulus.

(January 1999: M.C. 5) (January 2001: M.C.1)

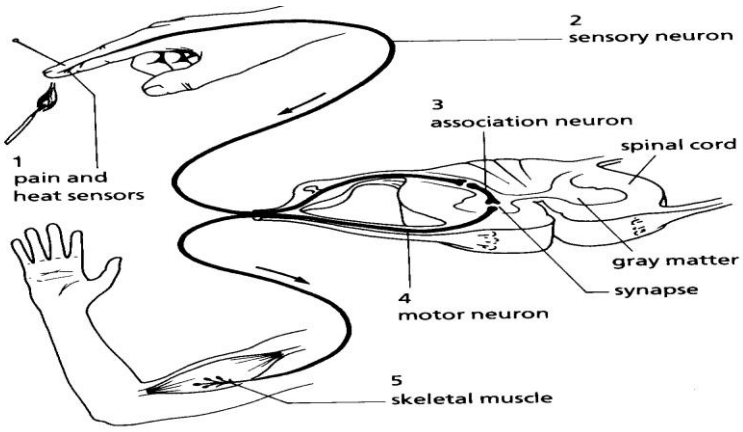


Diagram 9: The reflex arc.

• ***identifying the principal structures of the central and peripheral nervous systems and explaining their functions in regulating the voluntary (somatic) and involuntary (autonomic) systems of the human organism; e.g., cerebral hemispheres, cerebellum, pons, medulla, hypothalamus, pituitary, spinal cord, sympathetic and parasympathetic nervous systems*** pp. 385-395

I)Central Nervous System -- includes the brain and spinal cord

a) The Brain (see diagram 10)

The brain weighs about 2 kg. It has billions of neurons and an equal number of "glial" cells that support and nourish the neurons. It is connected to the rest of the body by the spinal cord and 12 cranial (found inside the skull or cranium) nerves. It has two distinctive layers:

1) the thin outer cerebral cortex, composed of nonmyelinated interneurons (gray matter). This layer produces most of the brain activities and has many folds and wrinkles that increase the surface area so there is more room for neurons. (see diagram 11)
2) the inner areas below the cerebral cortex are composed of hollow fluid filled spaces and bundles of myelinated neurons (white matter), leading to and from the cerebral cortex

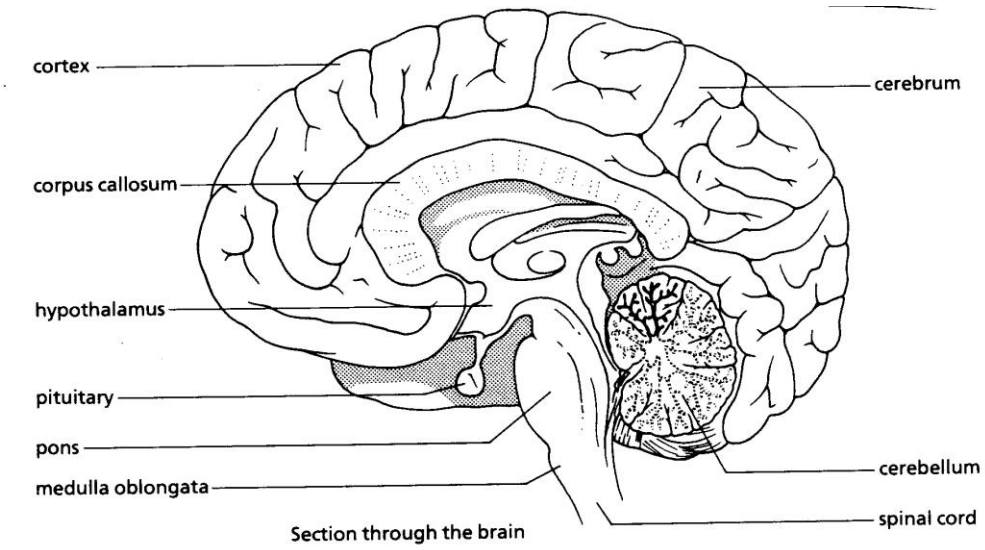


Diagram 10: The anatomy of the brain

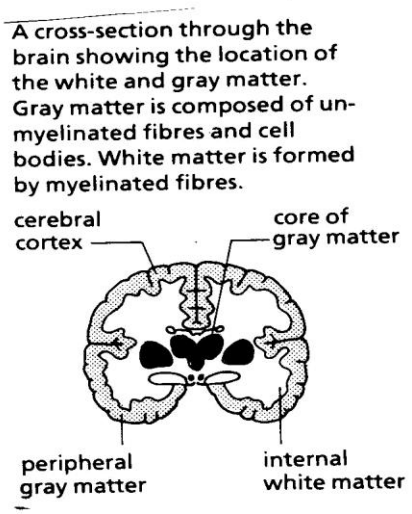


Diagram 11: Cross section through the brain

The brain is composed of several parts:

Cerebrum

This is the largest part of the brain. It is the major center of nerve control in our body and is developed to a far greater degree in humans than in any other animal. The outer surface (2-4mm) is the cerebral cortex. It spreads like a coat over the surface of the brain. All thoughts, memories, perceptions originate or are processed in the cerebrum. It its divided into two halves, called hemispheres, connected by a bundle of nerve fibers called the corpus callosum. It is believed the right hemisphere is responsible for more artistic, 3 dimensional, creative tasks, while the left hemisphere is for more analytic, problem solving, mathematics, logical tasks. The cerebrum/cerebral cortex has also been divided into 4 distinct lobes, each responsible for different tasks. (see diagram 12)

Lobe	Location	Task
Frontal	At the front	Voluntary muscle movements, basic intelligence, personality
Temporal	The sides	Hearing
Occipital	Low at the back	Vision
Parietal	The top and back	Skin sensory information and body position

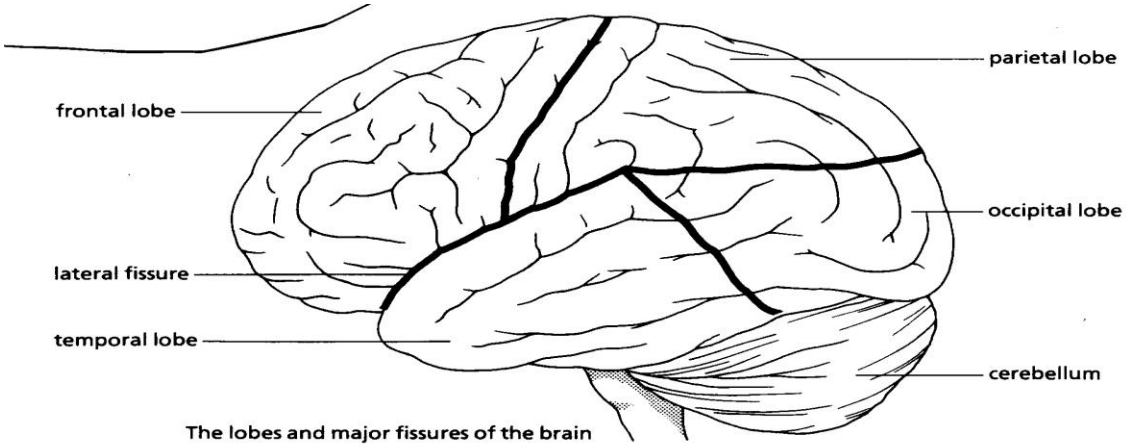


Diagram 12: The lobes of the brain

Cerebellum- responsible for balance, co-ordination of movement, and muscle tone
Medulla oblongata- receives and integrates signals from the spinal cord. It sends signals to the cerebellum and thalamus. It controls breathing and heart rate, as well as several autonomic functions such as dilation and constriction of blood vessels, coughing, swallowing, and vomiting.
Pons-it relays impulses between the medulla and other parts of the brain (cerebrum and cerebellum, right and left hemispheres)
Thalamus-it relays sensory impulses to the cerebral cortex and motor impulses from the cerebral cortex to the spinal cord
Hypothalamus- receives sensory impulses from the internal organs by way of the thalamus, and allows us to feel hunger, thirst, aggression, rage, and pleasure. It also controls the actions of the autonomic nervous sytems. It connects to and controls the pituitary gland which them controls the endocrine system
Pituitary gland- produces hormones that regulate other endocrine glands. Endocrine glands produce hormones that enter the blood. Exocrine glands produce other body fluids that leave the gland through tubes/ducts.
Midbrain- relays sensory impulses between the spinal cord and the thalamus and relays motor impulses between the cerebral cortex, pons, and spinal cord.
(June 2002 MC 4)
b) Brain protection (see diagram 13)
The brain and spinal cord are the most protected organs in our body. There are four structures that protect the brain and spinal cord:

1. Bone. The brain is surrounded by the skull and the spinal cord by all the vertebrae
2. Meninges. This is a 3-layer membrane that wraps around the brain and spinal cord. From outer to inner the layer names are dura mater, arachnoid layer, and pia mater
3. Blood brain barrier. Blood vessels in the brain act as a filtration system that selectively lets in molecules that the brain uses, such as glucose and amino acids, but will not allow most other chemicals that may normally be in the blood to pass into the brain fluids.
4. Cerebrospinal fluid. Tissues inside the brain produces a fluid that nourish cells and absorb shock from quick movements of the head.

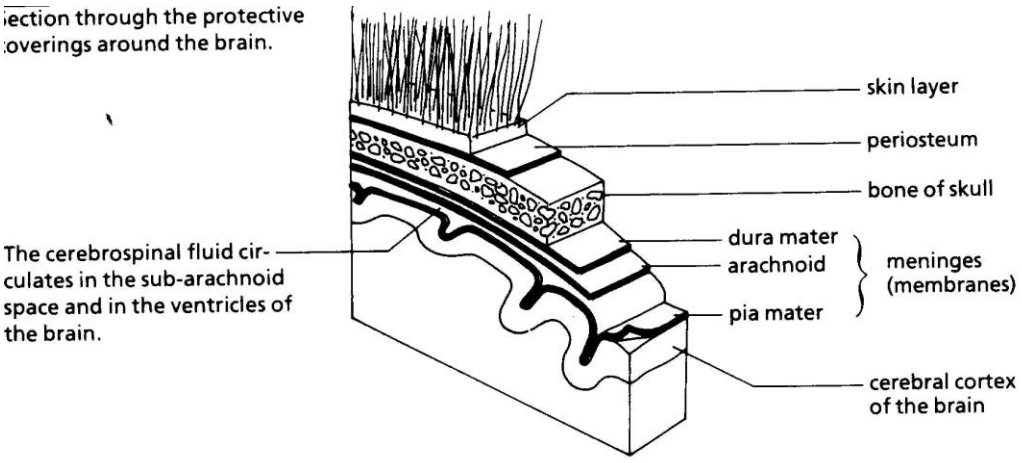


Diagram 13: Protective layers around the brain

(January 2002: M.C. 6) (June 2000: M.C. 3,4) (June 2004 MC 1)

c) Spinal cord (see diagram 14)

- As thick as a finger and made of over 10 billion neurons
- Grey matter on inside and white matter on outside (<1cm)
- Each bone (31) of the vertebrae in the spine has nerves passing from the cord out to the body.
- The dorsal root (back half of the spinal cord)is composed of sensory neurons.
- The ventral root (front half of the spinal cord)is composed of motor neurons.
- Gray matter (interneurons) carry impulses across the spinal cord (back to front) connecting sensory and motor neurons. It is this short connection that makes the quick connecting action of the reflex arc possible.
- The outer white matter of the spinal cord moves nerve impulses up and down the spinal cord, to and from the brain.

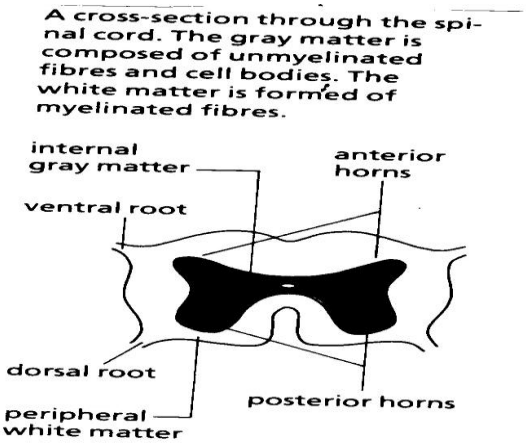


Diagram 14: Spinal cord anatomy

II)Peripheral Nervous System—include the somatic nerves (body nerves that extend to and from the spinal cord, the motor and sensory neurons) and the autonomic nerves (the autonomic nervous system), which are only motor neurons.

Autonomic Nervous System (see diagram 15) (pp. 396-399)
-is a subdivision of the peripheral nervous system, its nerves run separate from the spinal cord connecting the brain to the involuntary organs
-controls functions independent of our conscious control, ex: breathing, digestion, heart beat, hormones
-controlled by the hypothalamus and medulla
-the ANS functions through two motor nerves:

parasympathetic neurons: returns body back to normal	sympathetic neurons: prepares body for stres
-slow heart rate	-increase heart rate
-increase peristalsis	-decrease peristalsis
-pupil constriction	-pupil dilation
-increases stomach activity	-decreases stomach activity
-returns body to normal after an emergency	-prepares body for an emergency
-decrease blood flow to skin	-increases blood flow to skin

(June 2005: MC 1,6,7)

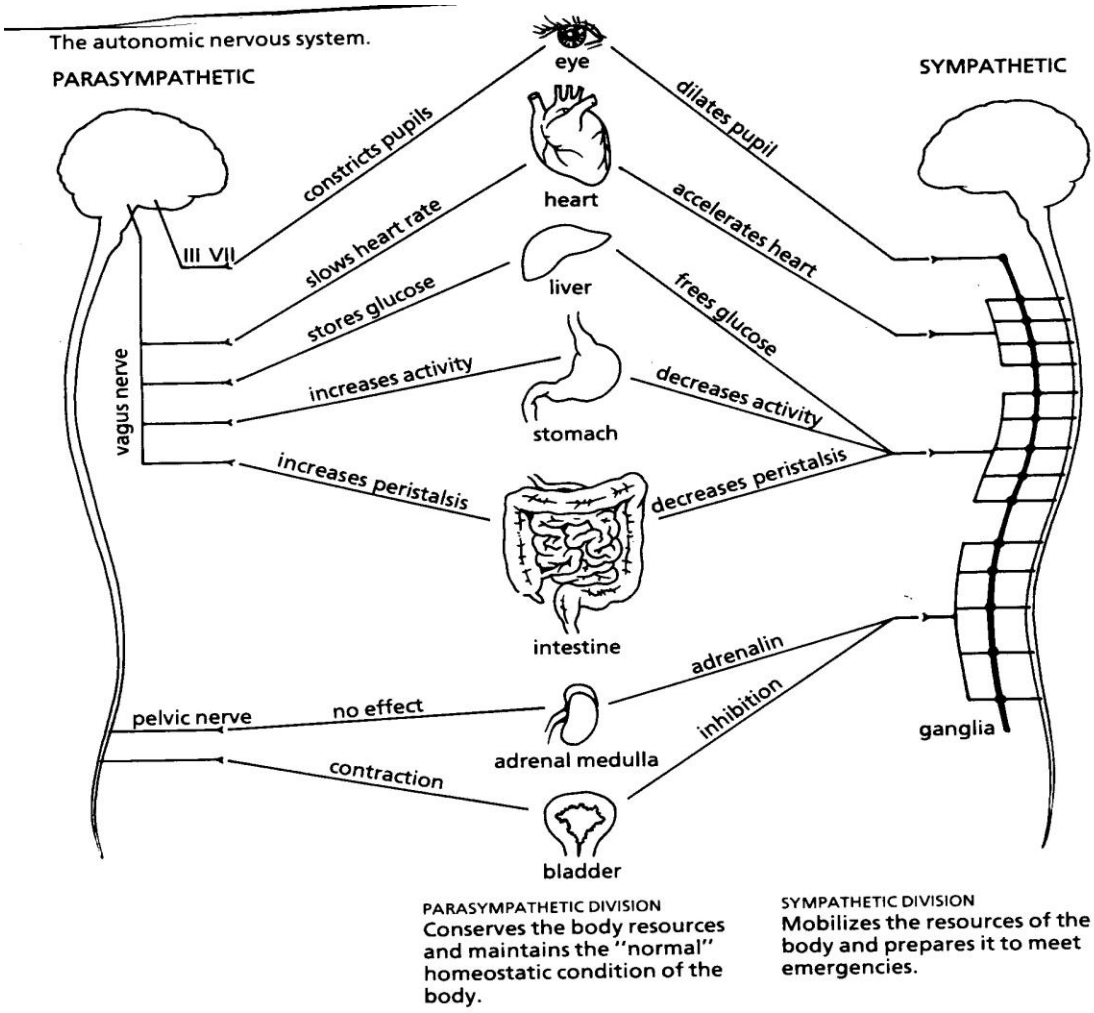


Diagram 15: The nerves of the Autonomic nervous system

Receptor Characteristics:

• ***explaining how human organisms sense their environment and their spatial orientation in it; e.g., auditory, visual, skin receptors, olfactory, proprioceptors.*** (pp.404-409)

1. all are connected to sensory neurons
2. stimulation of special cells in the receptor organ results in the production of an action potential
3. the stronger the stimulus the greater the frequency of action potentials produced by the cell
4. constant exposure to the stimulus leads to increased insensitivity to that stimulus, called sensory adaptation (may be decreased Ach. Production at the synapse). The receptor stops sending impulses, or decreases the frequency of impulses produced.

The following chart lists common receptors that are classified according to stimuli:

Chemoreceptor	Sensitive to chemicals (tongue, nose-olfactory) see diagrams 16, 17, and 18
Baroreceptor	Sensitive to pressure(found in the skin and blood vessels)
Osmoreceptor	Sensistive to fluid (water) levels(found in blood vessels)
Photoreceptor	Sensitive to light (eyes)
Mechanoreceptor	Sensitive to vibrations (ear)
Thermoreceptors	Sensitive to heat (skin, tongue)
Proprioreceptors	Sensitive to motion (found in tendons, muscles, and ligaments)

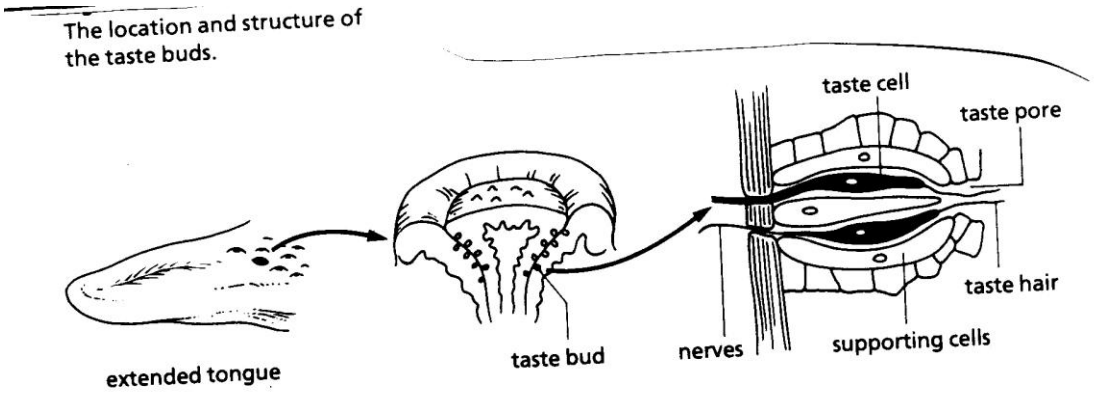


Diagram 16: The anatomy of taste buds

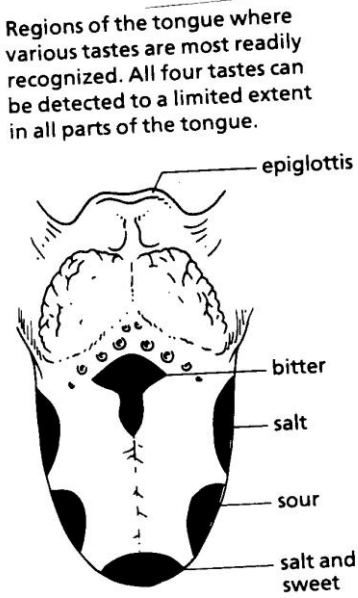


Diagram 17: Taste regions of the tongue

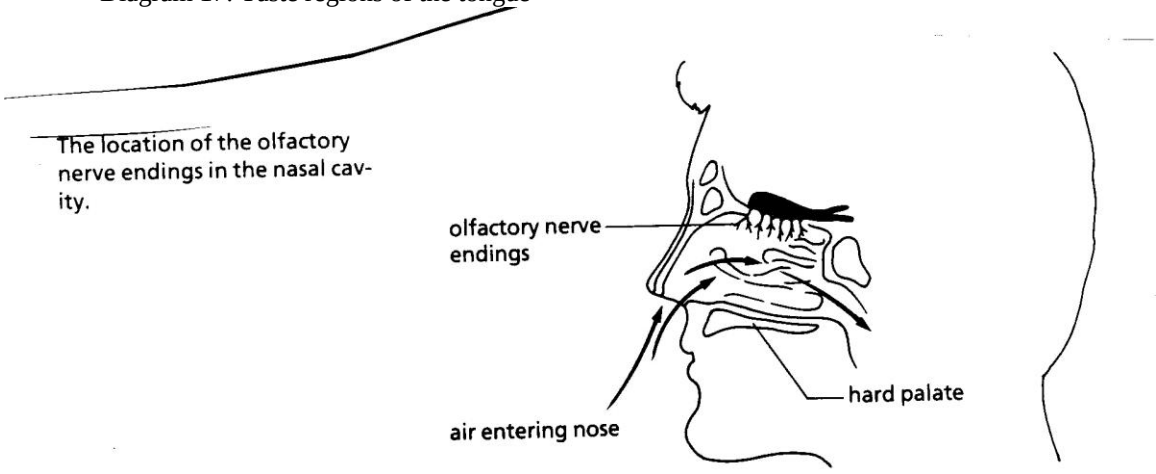


Diagram 18: Smell reception in the nose (Aug 2006: MC 3, June 2005: MC 2)

Eye parts and functions (pp.410-418)

Parts of the Eye refer to diagram 19	Functions
Eyelids and eyelashes	Protection of the eye
Extrinsic muscles	Movement of the eye, left to right, up and down
Sclera	White outer layer, protective, maintains shape of the eye
Choroid layer	Contains a black pigment that absorbs light preventing light from reflecting inside the eye
Retina (see diagram 20)	The inner layer of the eye, contains photoreceptor cells (rods and cones) that produce nerve impulses in response to light stimulus
Rhodopsin	When light hits this molecule it splits into Opsin and retinene that depolarizes the neuron, starting the nerve impulse. ATP and vitamin A are used to remake rhodopsin and restore the rod cell to its resting potential
Rod cells	Detect black and white light, respond to dim light, contain rhodopsin
Cone cells	Detect color, there are three types designed to detect red, green and blue light. Produce detailed vision. Greatest density in the fovea
Blind spot	Point at the back of the inside of the eye, on the retina, where are the axons from the neurons in the retina leave the eye forming the optic nerve. There is no room for rod or cones cells, consequently this tiny spot is blind.
Cornea	Transparent membrane on the front of the eye, focuses light on the lens and protects the eye
Iris	Circular muscle with a hole in the middle (pupil). It contracts to constrict the pupil when focusing on close up objects or light is bright, or relaxes to dilate the pupil when focusing on far away objects or when light is dim
Pupil	Hole in the middle of the eye that lets light pass through onto the lens
Fovea centralis	Tiny spot on the retina, composed only of cones, upon which light passing through the lens is focused.
Aqueous humor	Fluid in between the cornea and iris that maintains the shape of and nourishes the cornea
Vitreous humor	Fluid found behind the lens, helps maintain the shape of the eye
Ciliary muscles	Adjust the curvature (shape) of the lens focusing light on the retina
Lens	Focuses light on the fovea and retina

(June 2002 : MC 41, June 2004 MC 2)

Eye disorders

Eye disorder	Problem	Effect
Near sighted	Eye too long	Image focused before retina
Far sighted	Eye too short	Image focused after retina
Glaucoma	Build up of fluid in eye	Cuts off blood to retina=blindness
Cataract	Lens of cornea clouds	Block light to retina=blindness
Astigmatism	Irregular curvature of lens	Blurred vision

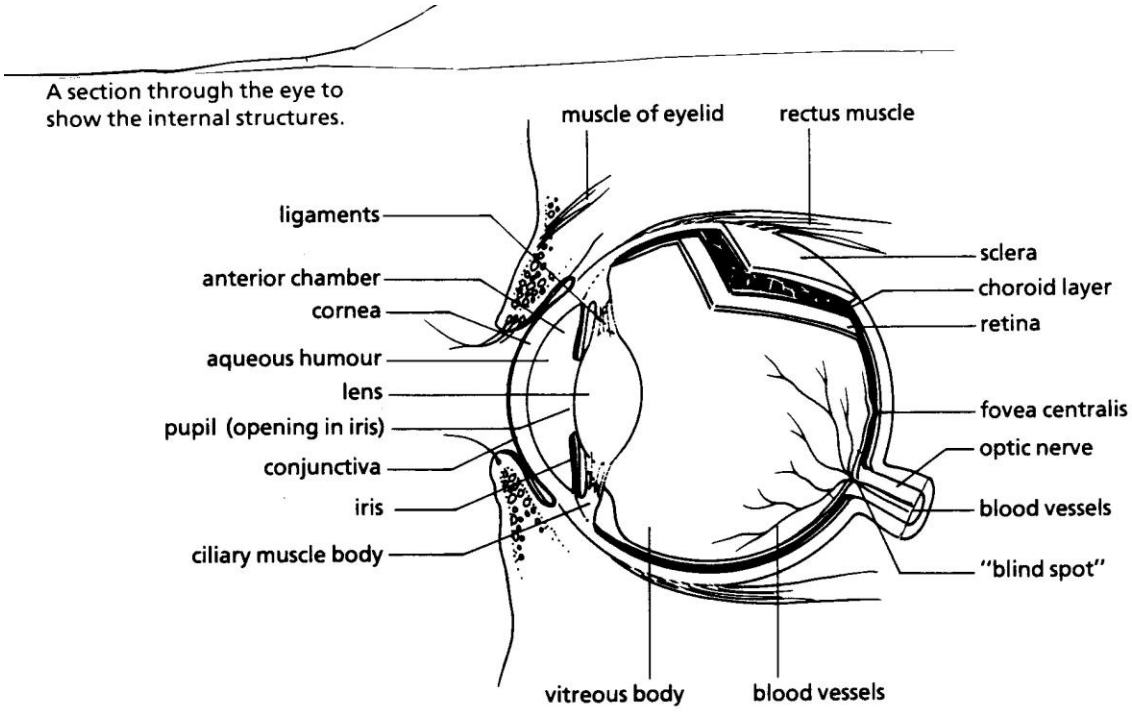


Diagram 19: The parts of the eye

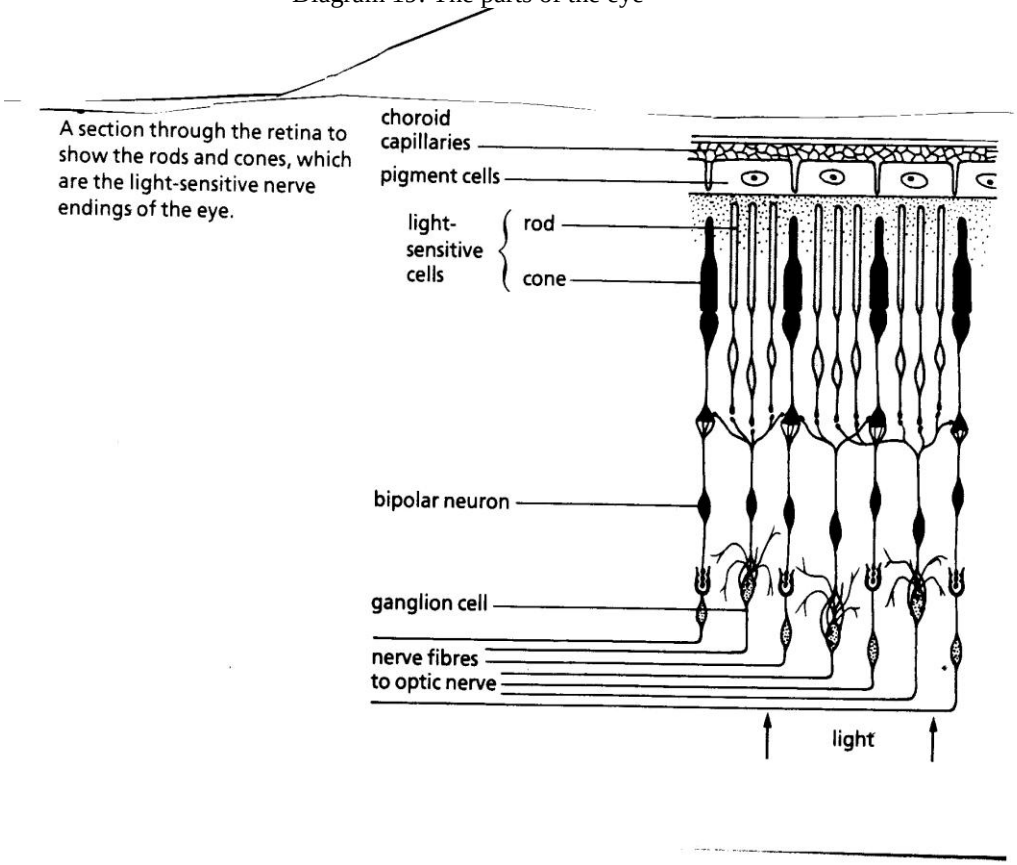


Diagram 20: The anatomy of the retina

Accommodation
The ability of the lens to change its shape to adjust focusing on near and far objects

Visual Acquity
The ability of the lens to focus detail

Sensory Adaptation of the eye
Switching from rods to cones or vice versa; increasing light intensity increases activity of cones and decreases activity of rods, and vice versa with decreasing light intensity

Ear parts and Functions (pp.419-426)

Parts of the Ear refer to diagram 21	Functions
Outer ear	Pinna, auditory canal, eardrum
Middle ear	Ossicles, oval window, eustachian tube
Inner ear	Cochlea, vestibule (utricle and saccula), semicircular canals
Pinna	Collect, funnel sound into the auditory canal
Auditory canal	Funnel sound to the eardrum
Tympanic membrane	Eardrum, vibrates in response to sound, causing ossicles to vibrate
Ossicles	Very small bones, hammer, anvil, stirrup, that amplify vibrations from the eardrum
Oval window	Small membrane on the cochlea that transmits sound into the cochlea
Eustachian tube	Connects the outer environment to the middle ear by way of the throat allowing air pressure to be equalized
Round window	Lets remaining motion out of the cochlea
Cochlea (see diagram 22)	Contains the organ of corti and the basilar membrane
Organ of corti (see diagram 23)	Made of many neurons that contain microscopic hairs that when moved (by vibrations) generate nerve impulses. Found inside the cochlea.
Basilar membrane	A membrane found below the hair cells at the organ of Corti. It anchors the hair cells in the organ of Corti (see fig 16.15 pg 398). Long hairs generate impulses interpreted as low sounds and short hairs are for high frequency sounds.
Vestibule	Chamber near the entrance of the cochlea that contains two soft sacs of fluid, the utricle and saccule
Utricle and Saccule (see diagram 24)	Contain fluid and tiny stones (otoliths) that stimulate sensory hairs to generate nerve impulses for position of the head (static equilibrium)
Auditory nerve	Sensory neurons that carry impulses to the temporal lobe from the cochlea
Semicircular canals (see diagram 25)	Fluid filled chambers containing sensitive nerve hairs that are responsible for detection of a change in motion (dynamic equilibrium)

(June 2003: NR 1)
Range of hearing is from 20-20,000 cycles per second (hertz)

Tenitus- temporary or constant ringing in the ear

Nerve Deafness- due to damage to sensory hair cells on organ of corti or auditory nerve or brain damage in the temporal lobe.

Conduction deafness- due to damage to the eardrum, ossicles , oval window, or basilar membrane.

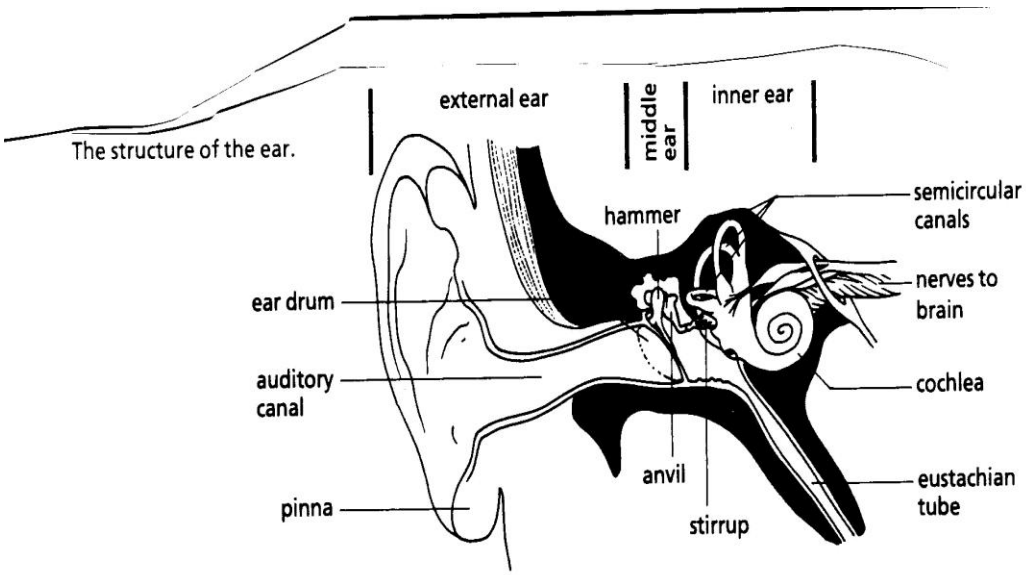


Diagram 21: The parts of the ear

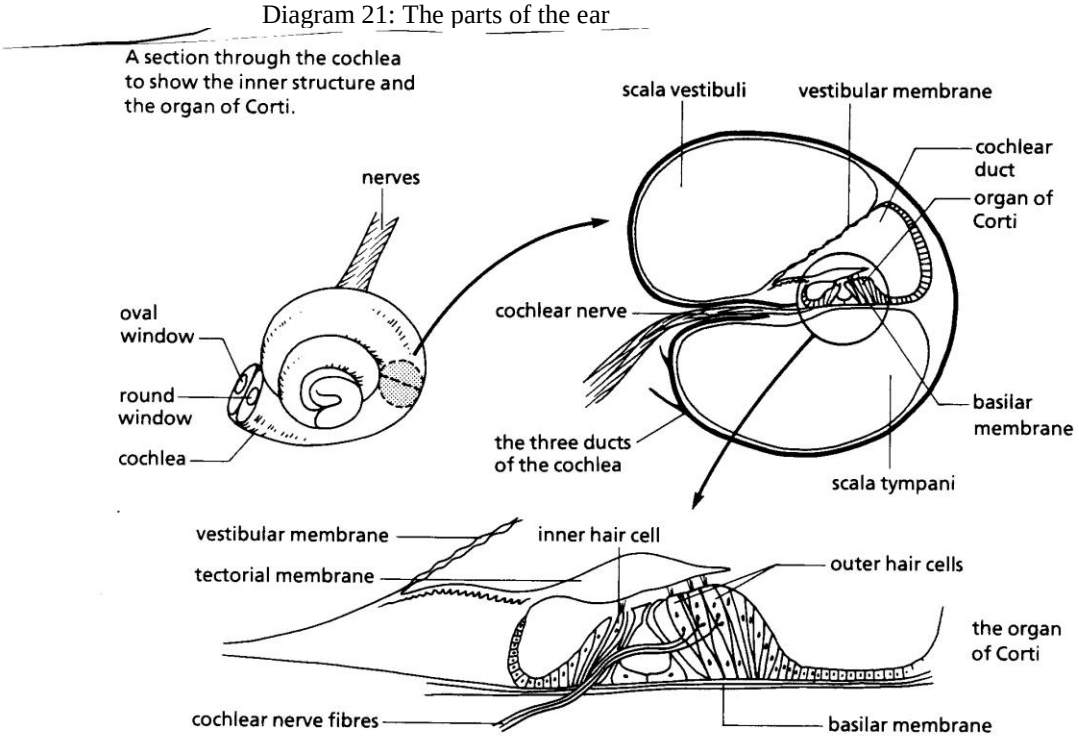
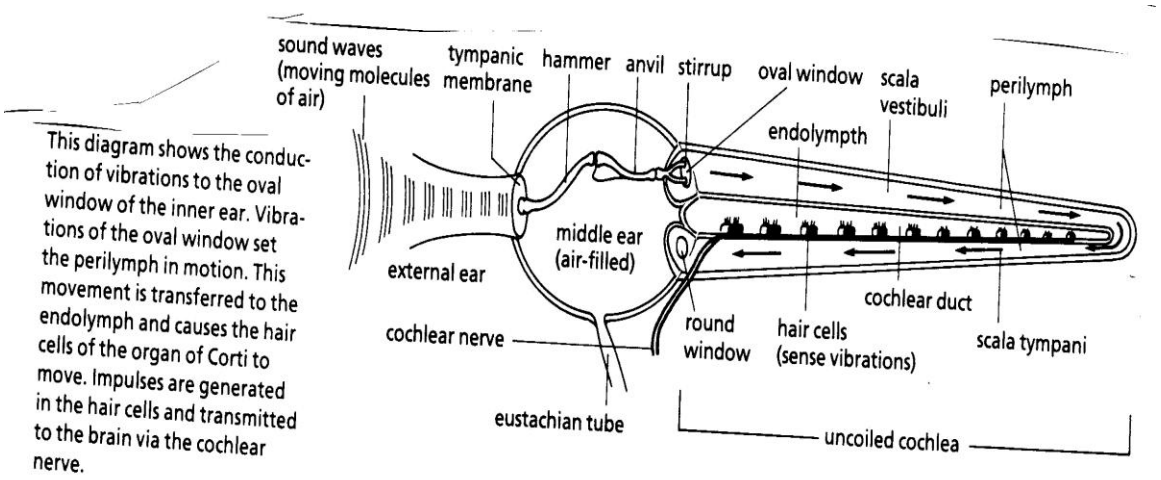
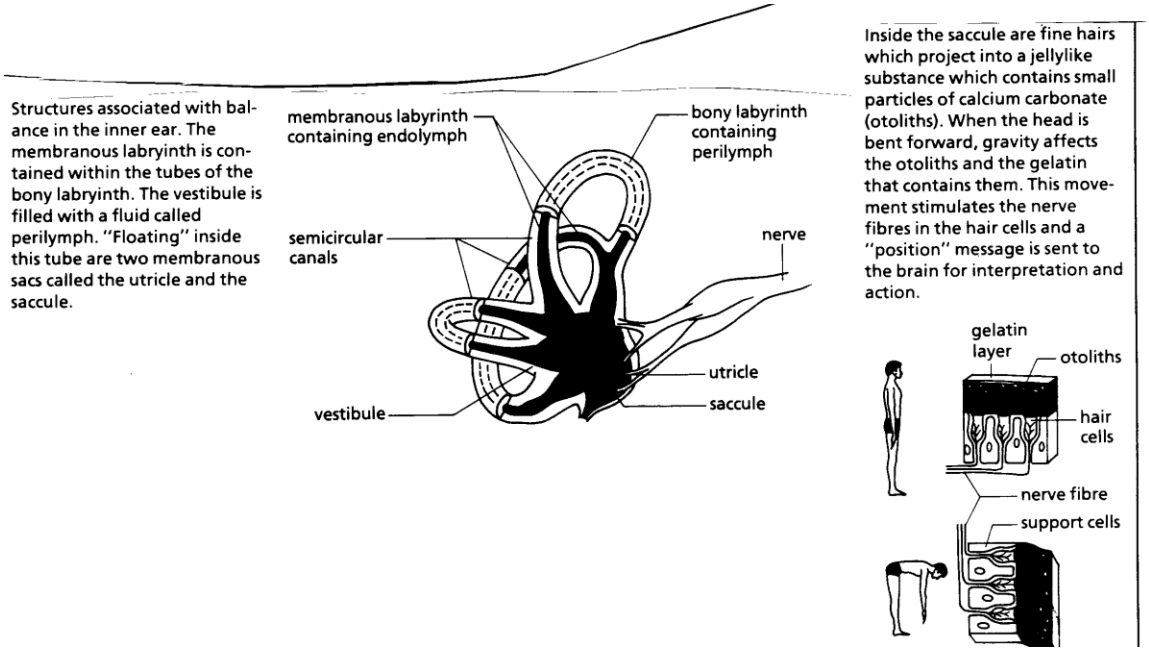


Diagram 22: The anatomy of the cochlea and organ of corti



This diagram shows the conduction of vibrations to the oval window of the inner ear. Vibrations of the oval window set the perilymph in motion. This movement is transferred to the endolymph and causes the hair cells of the organ of Corti to move. Impulses are generated in the hair cells and transmitted to the brain via the cochlear nerve.

Diagram 23: conduction of sound through the ear



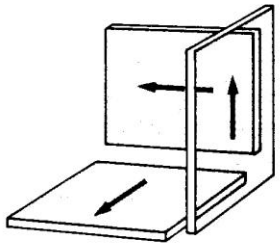
Structures associated with balance in the inner ear. The membranous labryinth is contained within the tubes of the bony labryinth. The vestibule is filled with a fluid called perilymph. "Floating" inside this tube are two membranous sacs called the utricle and the saccule.

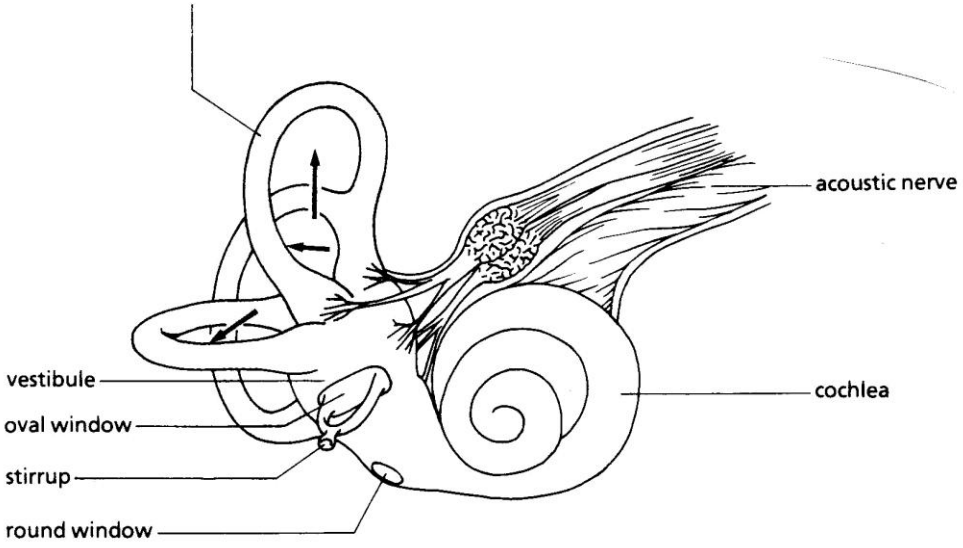
Inside the saccule are fine hairs which project into a jellylike substance which contains small particles of calcium carbonate (otoliths). When the head is bent forward, gravity affects the otoliths and the gelatin that contains them. This movement stimulates the nerve fibres in the hair cells and a "position" message is sent to the brain for interpretation and action.

Diagram 24: The utricle and saccule

The semicircular canals are in three planes at right angles to one another.

The semicircular canals. Try to imagine this shape carved out like tiny caverns and tunnels in the temporal bones of the skull.





(January 2000: M.C. 6)
(January 2001: M.C. 7,8)
(June 2000: M.C. 1,2)
(January 1999 M.C. 7)

2. The human organism maintains homeostasis through the use of complex chemical control systems.
- ***endocrine systems coordinate other organ systems through feedback to maintain internal homeostasis as well as the organism's equilibrium with the environment, by extending from Biology 20, Unit 4, the maintenance of metabolic equilibrium, and by:***
- ***identifying the principal endocrine glands of the human organism; e.g., the hypothalamus/pituitary complex, thyroid and adrenal glands, pancreas islet cells*** (page 436)

See diagram 26 for the locations of the principle endocrine glands.
Homeostasis- a process by which a constant internal environment is maintained despite changes in the external environment (ex. Reg of blood sugar)
Exocrine glands-produce secretions that are released into tubular ducts out of the body or into a body cavity. (ex. Saliva glands, liver, pancreas)
Endocrine glands-are ductless glands and generally produce hormones that are released into the blood (ex. Pituitary, pancrease, adrenal)
Hormones-a chemical produced by an endocrine gland that is released into the blood steam and causes a response in a target organ/tissue.
Target organ/tissue-the organ or tissue that is stimulated by or receives a specific hormone

The glands of the endocrine system and their general endocrine functions.

PITUITARY: the master gland, controls or influences all the other endocrine glands.

THYROID GLAND: influences the metabolic rate, decreases blood calcium.

PARATHYROID GLANDS: increase blood calcium.

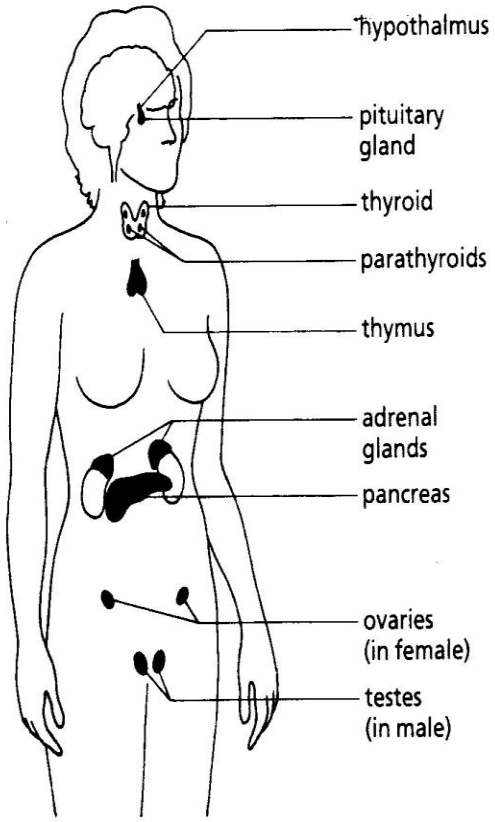
THYMUS: aids in immunity reactions in younger people.

ADRENAL GLANDS: help to prepare the body for stress.

PANCREAS: endocrine function is to control the blood sugar.

OVARIES: produce the female sex hormones; influence the secondary sex characteristics.

TESTES: produce the male sex hormones; influence the secondary sex characteristics of the male.



(Aug 2006: NR 1)

I) Protein hormones-include insulin, growth hormone, and adrenaline, they are all made from amino acids Protein hormones combine with specific receptor sites on the cell membrane of the target tissue and trigger the formation of cyclic AMP from ATP. Cyclic AMP acts as a messenger inside the cell, activating enzymes in the cell. (diagram 27)
II) Steroid hormones-include the male and female sex hormones and cortisol, which are made from cholesterol (a lipid/fat compound). The steroid hormone molecule passes into the cell, combines with a receptor molecule, and then activates a gene in the nucleus. The gene directs the production of a specific protein.(see diagram 27)

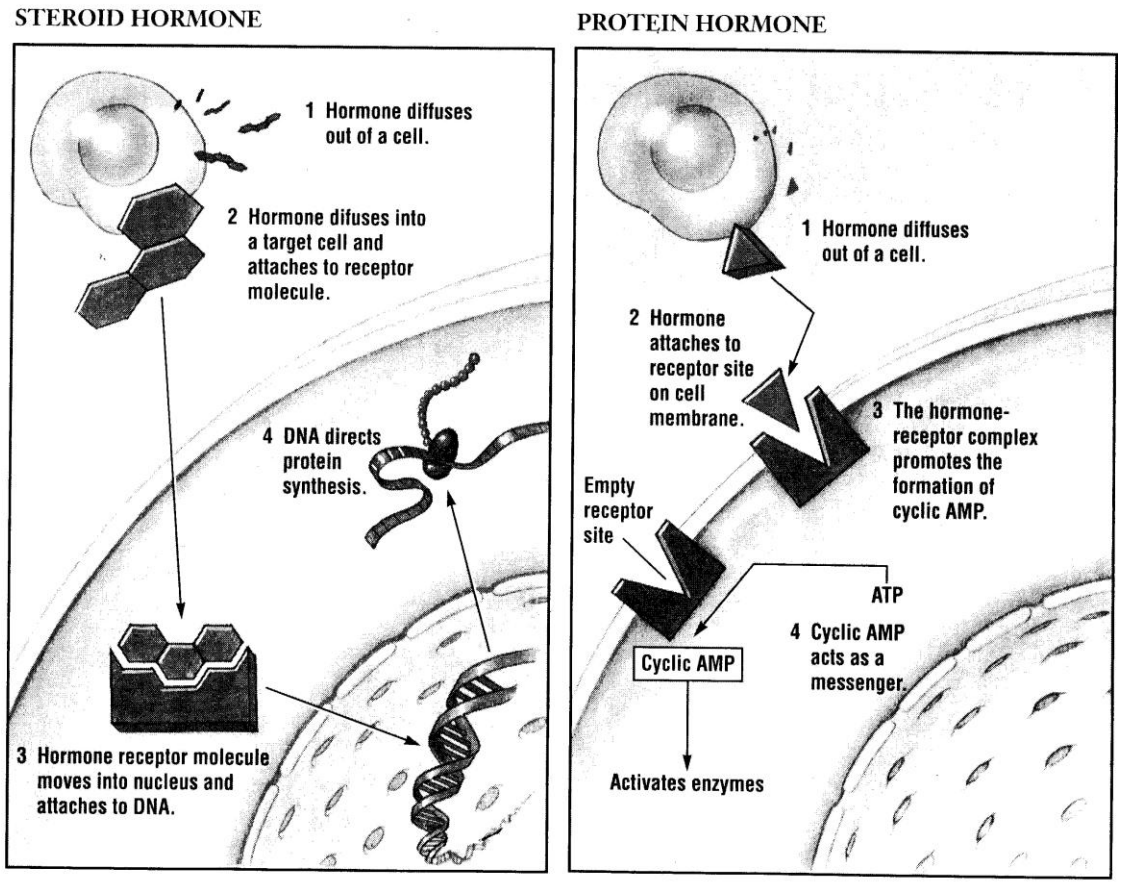


Diagram 27: The methods of hormone action

(January 2002: M.C. 1,2,3)

- ***describing the hormones of the principal endocrine glands; i.e., TSH/thyroxine, ACTH/cortisol glucagon/ insulin, HGH, ADH, epinephrine, norepinephrine, aldosterone*** (pg. 440)
- ***explaining the metabolic roles hormones play in homeostasis; i.e., thyroxine to metabolism, insulin to blood sugar regulation, HGH to growth, ADH to water regulation*** (pg.446-450)

Hormone	Gland produced by	Target tissue	Function/action
ADH	Posterior pituitary[1]	Kidney nephrons	Increases water reabsorption
Oxytocin	Posterior pituitary[1]	Uterus muscles, breasts	Contraction of muscles, secretion of breast milk
Growth hormone or somatotropin	Anterior pituitary[1]	All body tissues	Increase growth and metabolism
TSH	Anterior pituitary[1]	Thyroid	Increase thyroxin production
Thyroxin	Thyroid	Body cells	Increases metabolism
ACTH	Anterior pituitary[1]	Adrenal cortex	Releases cortisol and aldosterone
Adrenaline	Adrenal medulla	All body cells	Accelerate body reactions and functions
Aldosterone	Adrenal cortex	Kidney nephrons	Increased salt absorption
Cortisol	Adrenal cortex	Liver	Increased glucose production and release of amino acids
Calcitonin	Thyroid	Bones	Stimulates bones to remove calcium from the blood
Parathormone	Parathyroid	Bones	Stimulates bones to increase calcium in the blood
Insulin	Pancreas	Liver and muscles	Decreases blood sugar (glucose)
Glucagon	Pancreas	Liver and muscles	Increases blood sugar (glucose)
FSH	Anterior pituitary[1]	Ovaries and testes	Stimulates growth of egg and sperm cell
LH	Anterior pituitary[1]	Ovaries and testes	Causes ovulation and testosterone production
Estrogen	Ovary	Uterus, breasts	Secondary sex characteristics and growth of endometrium
Progesterone	Ovary	Uterus	Maintains endometrium and inhibits uterine contractions
Testosterone	Testes	Skin, muscles, bones, brain	Increases growth of sperm cells, body hair, muscles and bones
Inhibin	Testes(sertoli cells)	Pituitary	Inhibits FSH production
HCG	Chorion/placenta	ovary	Maintains corpus luteum progesterone production
Prolactin	Anterior pituitary[1]	Mammary glands	Stimulates and maintains milk production
MSH	Anterior pituitary[1]	Skin	Produces skin pigments

[1]note: refer to diagram 28 for pituitary hormones

(June 2000: M.C. 15) (June 2002: MC. 9, 10, 11, 12, 14) (June 2005: MC 8) (Aug 2006: MC 4) (January 2000: M.C. 9)

The hormones of the pituitary gland. Hormones of the posterior pituitary are secreted from the hypothalamus, trickle down into the posterior lobe, and enter the blood stream from there to be carried through the body. Anterior pituitary hormones are secreted by cells in the anterior lobe and enter the blood stream for transport throughout the body.

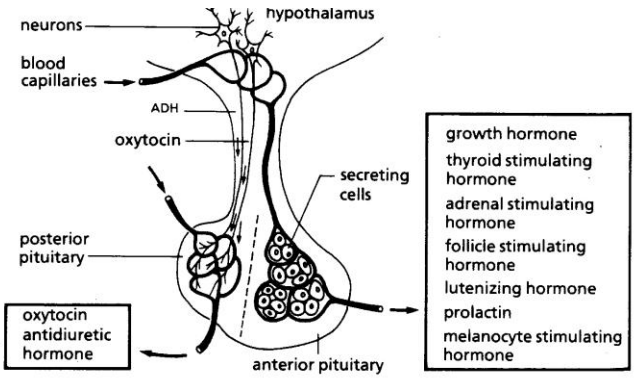
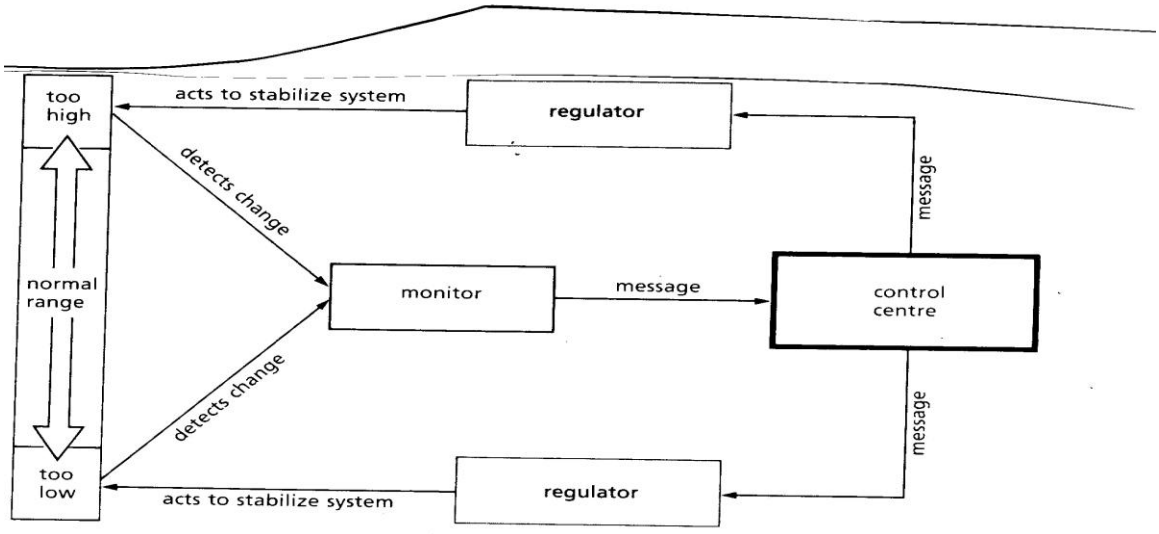


Diagram 28: The Pituitary gland and its hormones

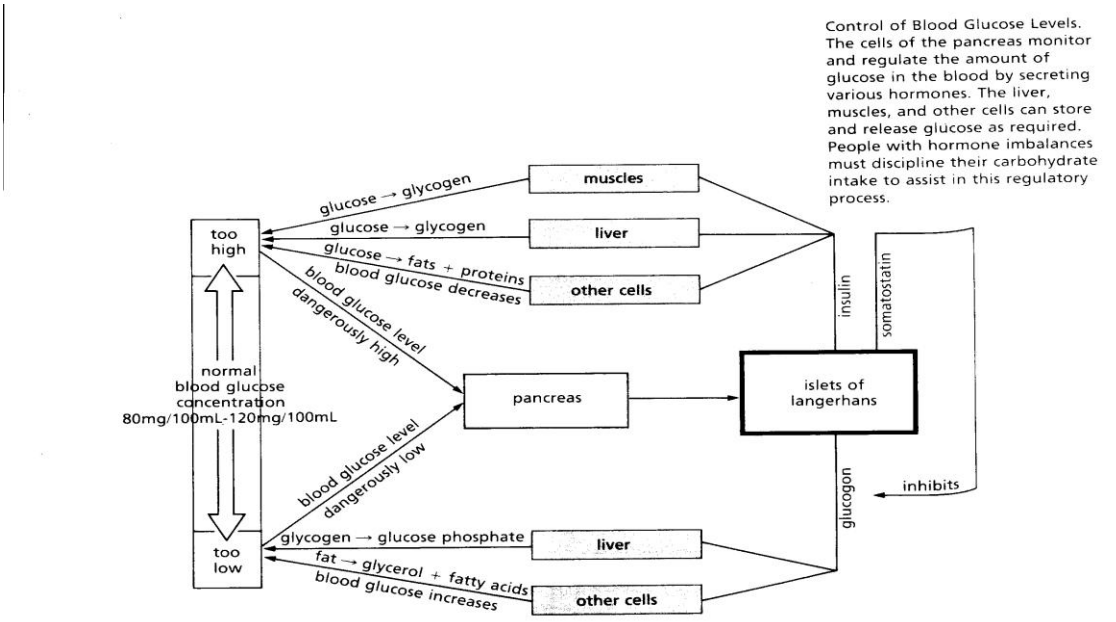
• ***explaining how the endocrine system allows human organisms to sense their internal environment and respond appropriately; e.g., sugar metabolism*** pp.456-462

Homeostasis refers to the processes that go on inside the body to maintain a constant internal environment. The process used to do this is called negative feedback (see diagrams 29 and 30). The word "negative" used here means the body will counteract a change. The common examples of this include regulating body metabolism by controlling thyroxin and maintaining proper blood sugar concentration by regulating insulin and glucagon production If blood sugar increases, for example after you eat supper, the body will try to decrease (store) the extra sugar by producing hormones (insulin) to affect the liver and muscles to convert the sugar into glycogen, returning the blood sugar concentration to normal (see diagram 31). Special cells in the pancreas, called Islet cells, respond to blood sugar level. There are two types of cells, alpha cells-which produce glucagon, and beta cells-which produce insulin. When blood glucose is low (exercise) the alpha cells release glucagon. Glucagon stimulates the liver and muscle cells to release additional glucose into the blood (convert glycogen into glucose) increasing blood glucose. When blood glucose is too high the beta cells release insulin. Insulin stimulates the liver and muscle cells to absorb more glucose (converting the glucose into glycogen) lowering blood glucose.



The Components of a Feedback System. Each component is differently coded. This pattern will be retained in the illustrations of feedback systems that follow.

Diagram 29: Components of a feedback system



Negative Feedback regulation of metabolic rate:
Metabolism: the sum of all the reactions that occur in the body cells. It can be measured through body temperature. High body temperature means higher metabolic rate. It is controlled by the interaction of three hormones. TRF, TSH, and Thyroxin. Body temperature can also be controlled through vasoconstriction and vasodilation, sweating, shivering, and goosebumps.

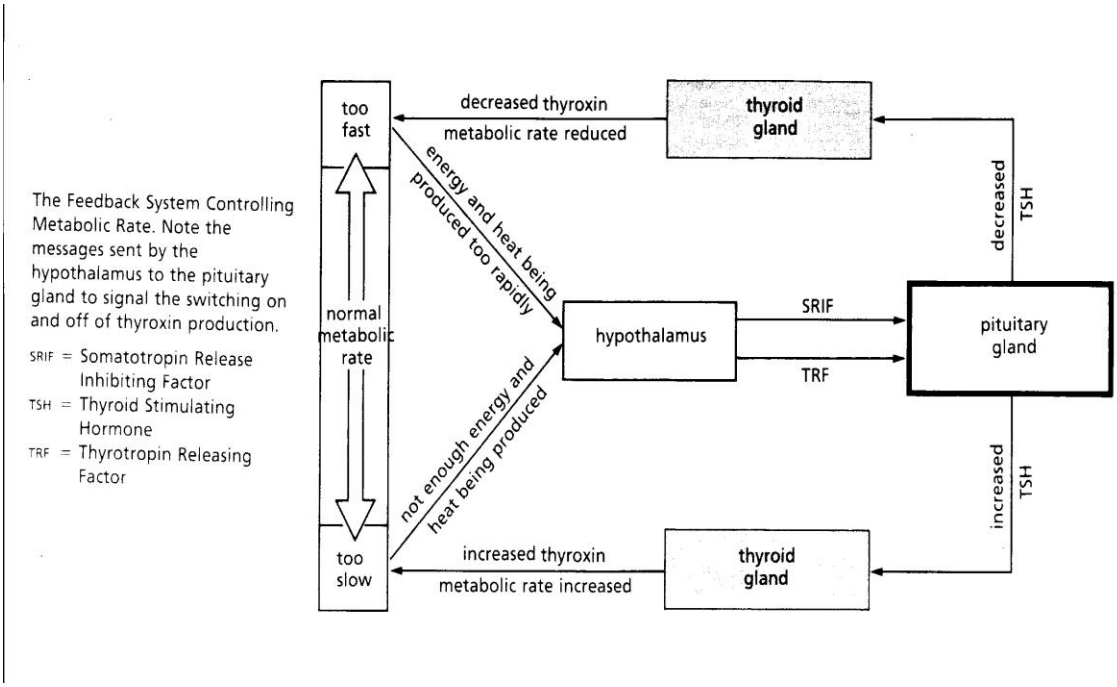


Diagram 30: Negative feedback of metabolic rate

Low body temp > hypothalamus > TRF > pituitary > TSH > Thyroid > Thyroxine > increased metabolism

Diagram 31: Negative feedback of blood sugar

(January 1999 : M.C. 11)
(June 2000: M.C. 6,7)
(January 2002: M.C. 5)

- ***comparing the endocrine and neural control systems and explaining how they act together; e.g., stress and the adrenal gland*** pp. 451-455

Comparison of nervous system to endocrine system

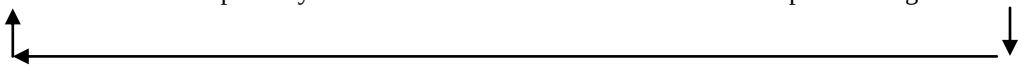
Characteristic	Nervous system	Endocrine system
Mode of action	Neuron	Blood stream
Method of action	Nerve impulse	Hormone
Response time	Immediate	Short-long term
Duration of effect	Short	Long

Stress: a physical or psychological stimulus that cause a change in the body, it alters homeostasis.
Drug: any substance, other than food, that alters normal body functions or is used to treat disease

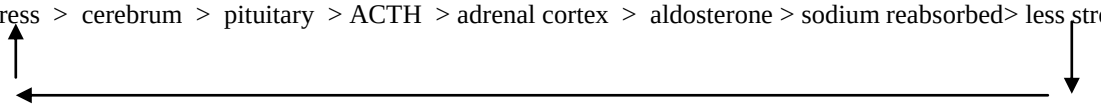
Adrenal Gland

- located on top of each kidney
- has 2 regions
- the outer cortex produces cortisol and aldosterone
- the inner medulla produces adrenalin
- cortex responds to ACTH from the pituitary
- medulla responds to ANS sympathetic and parasympathetic nerves

stress > cerebrum > pituitary > ACTH > adrenal cortex > cortisol > repairs damage > less stress



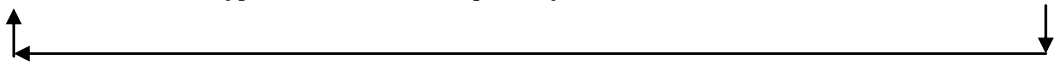
stress > cerebrum > pituitary > ACTH > adrenal cortex > aldosterone > sodium reabsorbed> less stress



Regulation of Water

Low water > low B.P. > hypothalamus shrinks > pituitary > increased ADH > kidney nephron

Low water > low B.P > hypothalamus shrinks > pituitary > increased ACTH > adrenal cortex > aldosterone



General Adaptation Syndrome

Shock: a sudden physical or mental disturbance.

In times of high stress both the nervous system and the endocrine system respond with a series of automatic responses grouped together as the 'general adaptation syndrome'. This includes the ANS responding with the sympathetic branch stimulating the heart rate and breathing directly, the pupil to dilate, and stimulating adrenal gland to produce adrenaline for immediate response to the situation. The pituitary gland will, at the same time, stimulate the thyroid to produce thyroxine, growth hormone, and ACTH, which will have longer lasting effects for recovery from the situation/stress event, to maintain homeostasis.

(January 1999: M.C. 11) (June 2002: MC 10, 11, 12)
(January 2001: M.C. 2) (June 2004: MC 4)
(January 2002: M.C. 10)

- ***describing, using an example, the physiological consequences of hormone imbalances.*** pp.436-462

Simple goiter- is a condition that is recognized by an enlarged thyroid gland. It is usually caused by a lack of iodine. The thyroid gland will not produce enough thyroxin or other thyroid hormones. The pituitary gland then overproduces TSH due to a lack of thyroxin in the blood. The overstimulated thyroid gland then begins to swell because it cannot produce thyroxin yet it is being stimulated to do so.

Myxedema- is caused by the underproduction of thyroid hormones without the increased TSH. It usually occurs after growth has been completed. The disease is characterized by weight gain, high blood pressure, hair loss, sluggishness and fluid collection in the tissues.

Giantism-is caused by the overproduction of growth hormone. Increased bone growth and over-growth of other tissues and organs in the body characterize it. In adults this is called adromegaly.

Hypoglycemia-occurs when the blood sugar level falls below normal. Too much insulin or not enough glucagon may cause it.

Diabetes mellitus (hyperglycemia)-this occurs when the blood sugar level is higher than normal. This is normally caused by the under-production of insulin by the beta cells in the pancreas (they are not working properly). Because blood sugar is high the kidney tubules (in the nephron) cannot reabsorb all the glucose from the urine back into the blood stream. As a result glucose appears in the urine and more water remains in the urine. Untreated diabetics are extremely thirsty due to loss of lots of water in the urine (they have to pee a lot)

(January 1999: M.C. 12)

UNIT 2
REPRODUCTION AND DEVELOPMENT

1. Humans and other organisms have complex reproductive systems that ensure the survival of the species.
- ***human organisms have evolved a specialized series of ducts and tubes to facilitate the union of an egg and sperm, by:***
- ***describing hormonal and chromosomal factors and explaining the physiological events resulting in the formation of the primary (gonads) and secondary (associated structures) reproductive organs in the female and male fetus***

Males posses an X and Y chromosome, females two X-chromosomes. Whether an embryo develops into a male or female appears to be determined by a gene located on the Y chromosome. This gene is thought to function as the master switch of sexual development, turning on other genes (at around 38 days) that lead to the differentiation of the primitive gonads into testes and of the germ cells into spermatogonia (sperm cells). In its absence, the gonads develop as ovaries and the germ cells become oogonia (egg cells). In addition to the action of a master gene, interactions between the germ cells and the primitive gonads are necessary for development of the testes to proceed. As the testes form, they begin their secretion of androgens, testosterone, and under the influence of androgens, the external genitalia and other structures become masculinized. If a female embryo is exposed to androgens, it will become similarly masculinized, although, gonadally speaking, it will be female.
(June 2000 MC 23) (June 1999 MC 19)

- ***identifying the structures and describing their functions in female (e.g., ovaries, fallopian tubes, uterus, cervix, vagina) and male (e.g., testes, epididymus, vas deferens, seminal vessicles, prostate gland, penis) reproductive systems*** pp.478-485

I) Male Reproductive anatomy. (see diagrams 32 and 33)

1. The testes are composed of seminiferous tubules that produce the male gametes, the sperm cells (see diagram 34). The gametes are cells that have half the chromosome number (23). They are called haploid (meaning half), diploid means they have the total number of chromosomes (46). The chromosomes are found in the nucleus. The acrosome contains enzymes that are used to break through the outer layer of the egg during fertilization. The middle piece contains many mitochondria that provide the energy for movement of the tail.
2. The interstitial cells surround the seminiferous tubules and produce testosterone.
3. Sperm cell production occurs in the seminiferous tubules that unite and store sperm cells in the epididymus. This is called spermatogenesis (gametogenesis). About 300 million immature sperm cells are made every day. If they are not used they get reabsorbed by the seminiferous tubules (diagram 35)
4. Spermatogonia are the parent cell (46 chromosomes) that divides by meiosis to produce 4 haploid spermatocytes (23 chromosomes) cells. Sperm cell production is best a few degrees below body temperature. The rapid division of cells produces heat. This heat can destroy the cells produced. This is why the testes are found outside the body suspended in the scrotum.
5. Sertoli cells, found inside the seminiferous tubules, provide nourishment and anchor the developing sperm cells. They also produce the hormone inhibin (inhibits male FSH and LH)(see diagram 35)
6. Semen is composed of four parts:
    a. Sperm cells from the testes
    b. Fructose solution from the seminal vesicles. This provides energy for the movement of the tail of the sperm cell. The seminal vesicle fluid also has prostaglandin's (hormones) that cause contractions of the muscles of the uterus to help the sperm cells move.
    c. Sodium bicarbonate buffer from the prostate gland. This protects sperm cells from the acidic environment of the vagina. The prostate gland contracts during an ejaculation to move the semen out into the urethra through the vas deferens
    d. Cowper's gland produces a fluid that neutralizes the acid in the male urethra and assists in sperm cell movement.
7. FSH (from the pituitary gland) stimulates the seminiferous tubules to produce sperm cells.

8. Prepuce/foreskin is loose skin that covers the glans. This can be surgically removed (circumcision)
9. LH produced by the pituitary gland stimulates the interstitial cells between the seminiferous tubules to produce testosterone. FSH and LH are gonadotropins: hormones that stimulate the gonads.

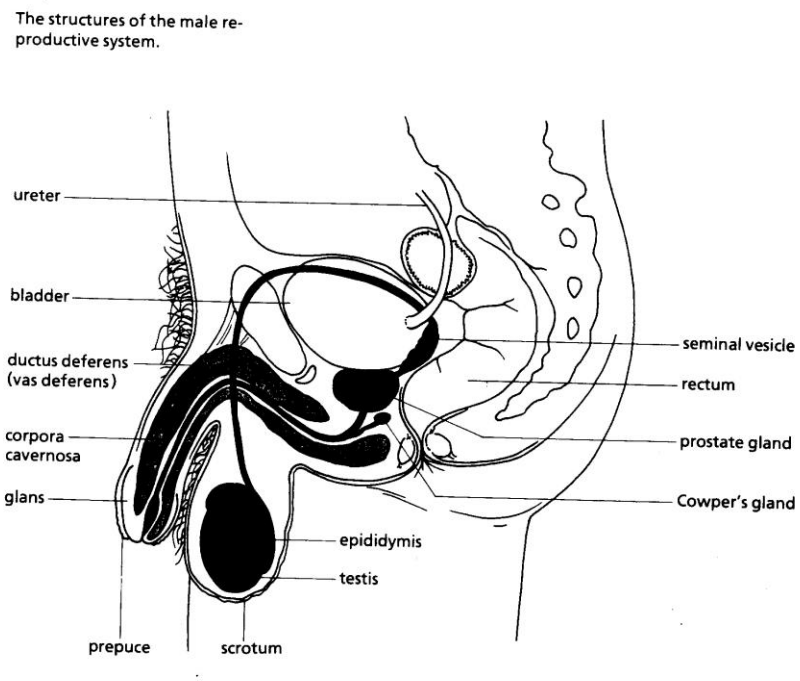


Diagram 32: The male reproductive anatomy

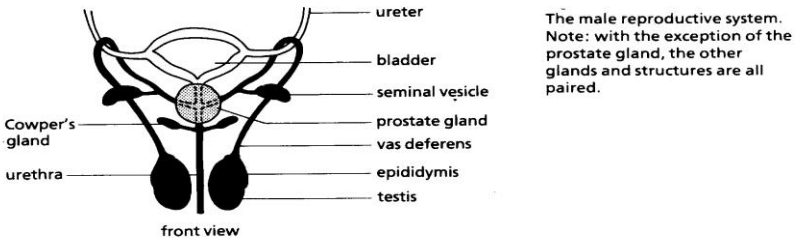


Diagram 33: The male reproductive anatomy

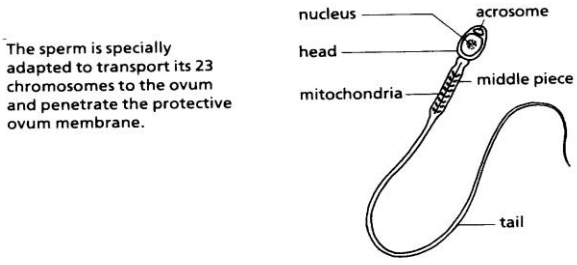


Diagram 34: The anatomy of a sperm cell
(June 2002: MC 15, June 2004 NR 1, Aug 2006 MC 5)

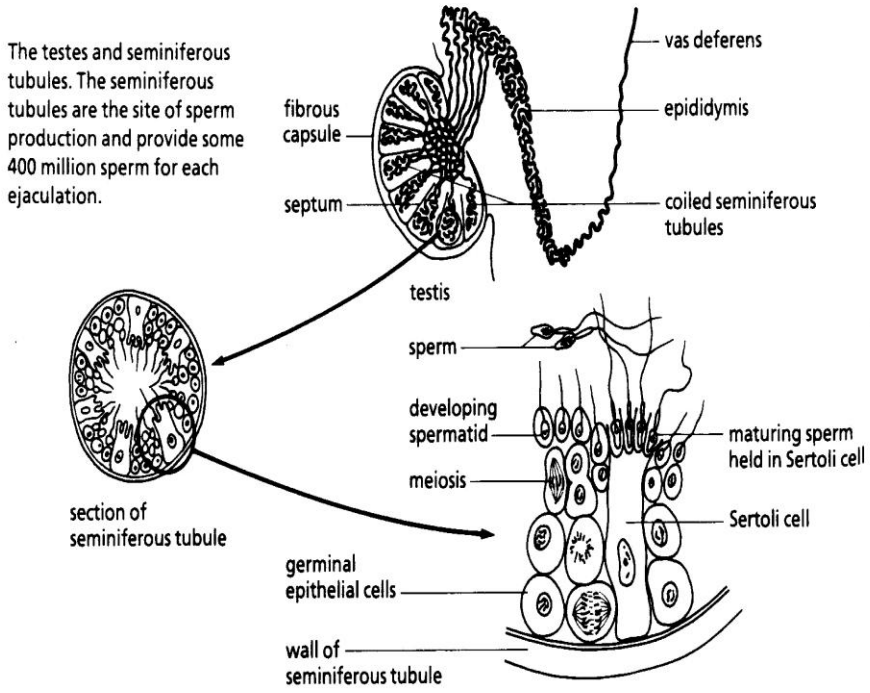


Diagram 35: The anatomy of the testes

II) Female reproductive anatomy (see diagram 36)

1. Eggs/ova/ovum, are produced in the ovaries in a process called oogenesis (gametogenesis)
   There are two ovaries located in the abdominal cavity
   The eggs grow in follicles,(see diagram 37)) which are circular clusters of cells that surround the egg
2. Each ovary has about 2 million eggs at birth, only 300,000 survive to puberty and only 450 mature throughout the reproductive life span of the woman.
3. The eggs are haploid, produced by meiosis. Unequal division of the cytoplasm results in only one cell surviving of the 4 daughter cells. The other 3 cells, called polar bodies, degenerate (see diagram 53)
4. FSH stimulates egg production, while LH stimulates release of the egg (ovulation) (see diagram 37).
5. During the development of the egg the follicle cells produce estrogen. After ovulation the follicle cells, now called the corpus luteum, now produce progesterone (see diagram 37).
6. The egg is swept into the fallopian tube by fimbrae, finger like folds around the opening of the fallopian tube (oviduct)
7. The fallopian tubes connect to the uterus. If the egg is fertilized it will attach to the inner lining of the uterus called the endometrium. The uterus (womb) is the location where the embryo grows to a fetus.
8. The opening from the vagina to the uterus is a circular muscle called the cervix. This muscle helps to hold the growing fetus in the uterus in the later stages of pregnancy and must dilate to allow the baby to be pushed out the uterus (see diagram 38).
9. Vulva is the name given to the external structures, the labia and clitoris
10. Hymen is a membrane that partially covers the entrance to the vagina
11. Several days before ovulation the vagina begins producing mucus. This provides a better environment for the survival and movement of the sperm cells.

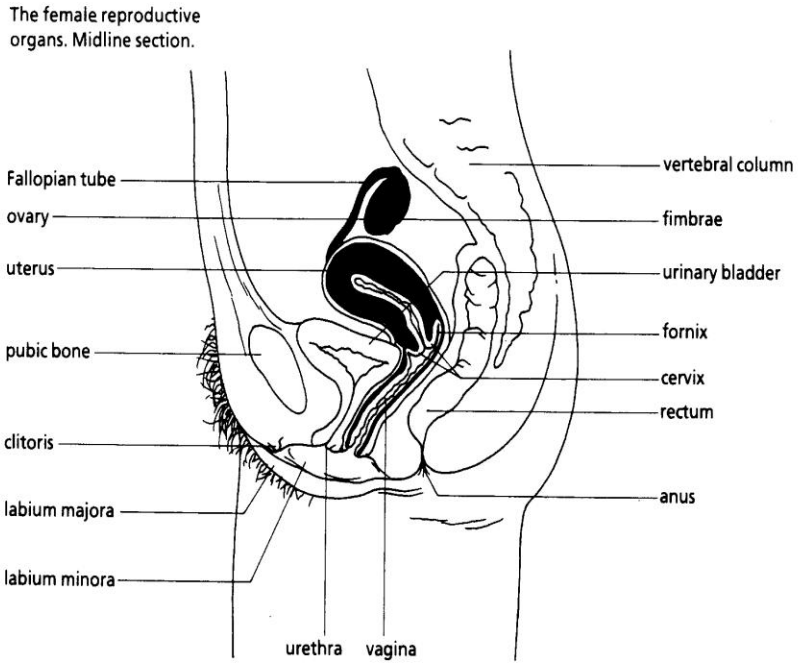


Diagram 36: The anatomy of the female reproductive system

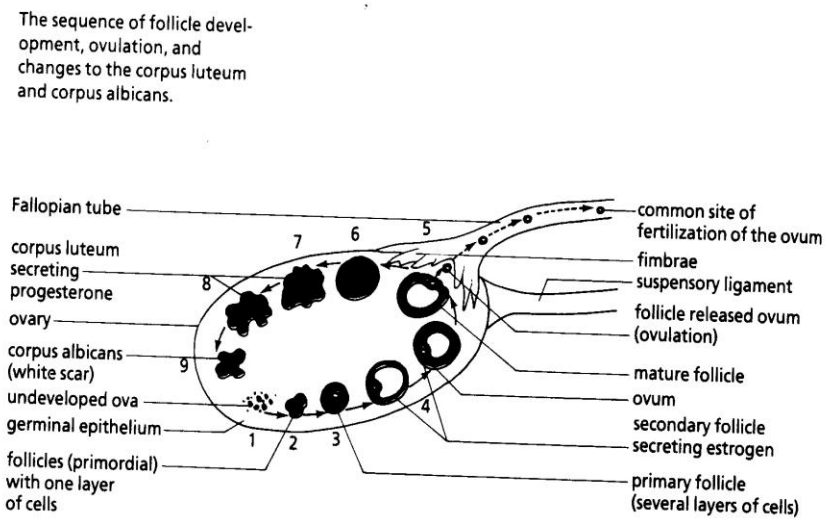


Diagram 37: Events that occur inside the ovary

The female reproductive organs and the pathways of sperm and ovum to the normal site of fertilization. Note: from the main diagram (A) it would appear that the vagina and the uterus are in a straight line. Diagram (B) shows that from the side, the two organs are at right angles to each other.

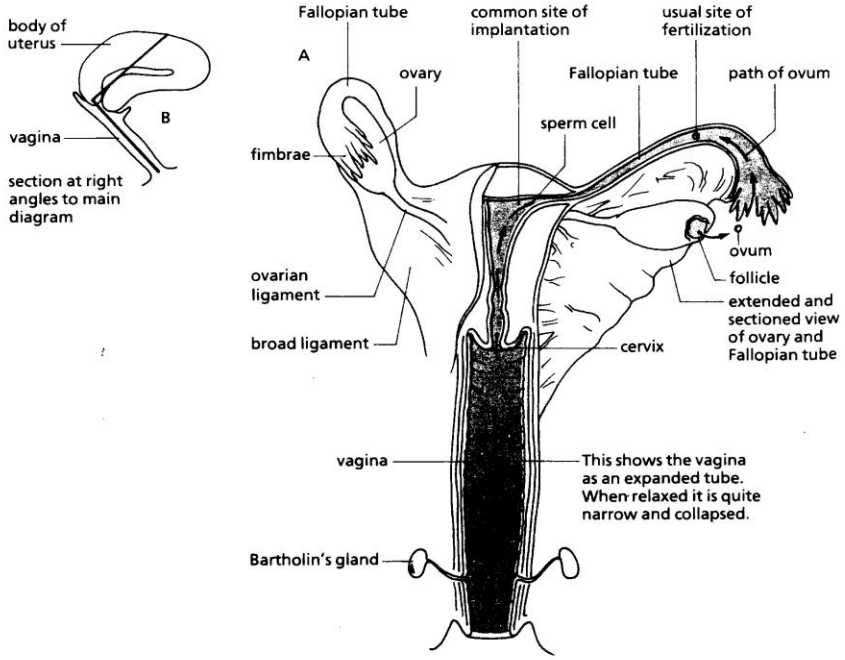


Diagram 38: Female anatomy: sites of significant events

(June 2000 NR 3, MC 16,18,19,24) (January 2000 MC 13) (January 1999 MC 14) (June 1999 MC 22) (June 2002: MC 15, 16)

• ***explaining how sexually transmitted diseases can interfere with the passage of eggs and sperm; e.g., chlamydia, gonorrhea.***pp.486-491

Gonorrhea- is caused by a bacterium that attacks the urogenital tract and rectum and may also attack joints (causing arthritis), the brain and the cardiovascular system. In male symptoms include frequent urination, and burning sensation at the tip of the penis within several days to a week after sexual intercourse. Scars can form in the reproductive tract and cause infertility in the male and female. In the female there may be no symptoms, which facilitates the spread of the disease. If the female does show symptoms she also will experience a burning sensation at the end of the urethra and need to urinate often. The cervix may also become infected.

Chlamydia-caused by a bacteria and develops symptoms similar to gonorrhea. It can lead to pelvic inflammatory disease in females and males can experience problems with the prostate gland and testes

STD's cause infections in the tubes that carry the sperm or egg, or infections in the reproductive organs of either male or female. Theses infections can cause temporary or permanent blockage of the tubes, or temporary or permanent cessation of function of the organ infected. The result can be temporary infertility, permanent infertility, or secondary effects on other organs (endometriosis).
(June 1999 MC 27)

2. Reproductive success of organisms is regulated by chemical control systems.
- ***the development of sexual anatomy and sexual functioning is influenced by hormones, by:***
- ***describing the role of hormones in the regulation of primary and secondary sex characteristics in females and males*** pp.492-500

Primary and secondary sex characteristics in males and females. The primary organs are the ovaries and testes while the secondary organs are the associated organs of the reproductive system.

Sex characteristics	Males	Females
Primary	Testes, sex organ development	Ovary, sex organ development
Secondary	Body hair, muscles, bones	Breast development, skeletal changes

(June 2000 MC 25) (June 1999 MC 18)

- ***identifying the principal reproductive hormones in the female and explaining their interactions in the maintenance and functioning of the female reproductive system; e.g., estrogen, progesterone, LH, FSH, prolactin, oxytocin*** pp.492-500

a) Follicle stimulating hormone- is produced by the pituitary and stimulates the growth of a follicle in the ovary. Low levels of estrogen and progesterone stimulate the pituitary to produce FSH. High levels of estrogen and progesterone inhibit the pituitary production of FSH.

b) Luteinizing hormone- is produced by the pituitary and brings about ovulation. Is inhibited by high levels of estrogen and progesterone. (FSH and LH are called gonadotropins)

c) Estrogen –is produced in the ovary by the growing follicle. It is responsible for the development and maintenance of the female reproductive structures, especially the endometrium (lining of the uterus), and secondary sex characteristics. It causes the growth of the endometrium during the first 2 weeks of the menstrual cycle preparing it for the arrival of fertilized egg. High levels of estrogen inhibit FSH. Estrogen is produced in smaller amount by the corpus luteum after ovulation. If fertilization and implantation does not occur the corpus luteum degenerates, resulting in the shedding of the endometrial lining due to low estrogen levels (menstruation). Low estrogen levels during the menstrual phase act as a stimulus for FSH secretion by the pituitary. This in turn leads to increased estrogen from the developing follicle.

d) Progesterone-is produced in the ovary by the corpus luteum. Once ovulation has occurred the follicle is now called the corpus luteum. Progesterone works with estrogen to prepare (maintain) the endometrium for implantation of a fertilized egg. It also prepares the breasts to secrete milk, and inhibits uterus contractions during pregnancy. If no fertilization occurs, rising levels of progesterone and estrogen inhibit LH secretion by the pituitary inhibiting further ovulation. With no implantation the corpus luteum degenerates resulting in a drop in progesterone and estrogen and the endometrium is shed (menstruation). The degenerated corpus luteum is now called the corpus albicans.

e) Prolactin – is the hormone responsible for milk production during breast-feeding. When the baby sucks on the nipple nerves in the nipple and areola send signals to the brain (hypothalamus/pituitary). The pituitary then responds by releasing prolactin causing both breasts to release milk

f) Oxytocin- the main hormone responsible for contraction of the muscles of the uterus during labor. It is produced by the pituitary gland. Progesterone inhibits the pituitary production of oxytocin. A few weeks prior to birth progesterone production begins to decline with a resulting increase in muscle contractions of the uterus (false labor). As progesterone production declines further the contractions get stronger and more regular up to and throughout the delivery/birth.

The Menstrual Cycle

Estrogen, progesterone, FSH, and LH all interact in the female reproductive system to produce the menstrual cycle. This cycle is described in four distinct stages (see diagram 39).

1. Menstrual phase- this is the first few days (1-5) when menstrual bleeding occurs (called menstruation). Estrogen and progesterone are at their lowest causing the endometrium to be shed (Menopause is the time at the end of a womans reproductive years when the menstrual cycle ceases).
2. Follicle phase-occurs from day 5 to day 13. Low estrogen causes the pituitary to produce FSH. The FSH causes a follicle to start developing in the ovary, which begins producing estrogen, which in turn causes the endometrium to begin to grow again.
3. Ovulation- at around day 14, stimulated by LH, the egg is released from the follicle
4. Luteal phase- from day 14 to day 28 the corpus luteum produces progesterone and estrogen. These hormones inhibit LH preventing further ovulation. If the egg is not fertilized and implanted in the endometrium then the corpus luteum degenerates around day 22 and eventually stops producing progesterone and estrogen (the corpus luteum is now called the corpus albicans). The low levels of these hormones result in the shedding of the endometrium (menstruation) and the cycle starts all over. If implantation does occur then the embryo begins producing HCG that stimulates the corpus luteum to continue to produce progesterone, preventing menstruation, and the menstrual cycle is suspended during pregnancy.

1. The **menstrual phase**. This covers the time of menstrual flow, when the endometrial wall is shed.
2. The **follicular phase**. This involves the building up of the endometrium as a result of estrogen being received by the uterus.
3. The **luteal phase**. This occurs after the ovary has released the ovum and progesterone is maintaining the endometrial lining.

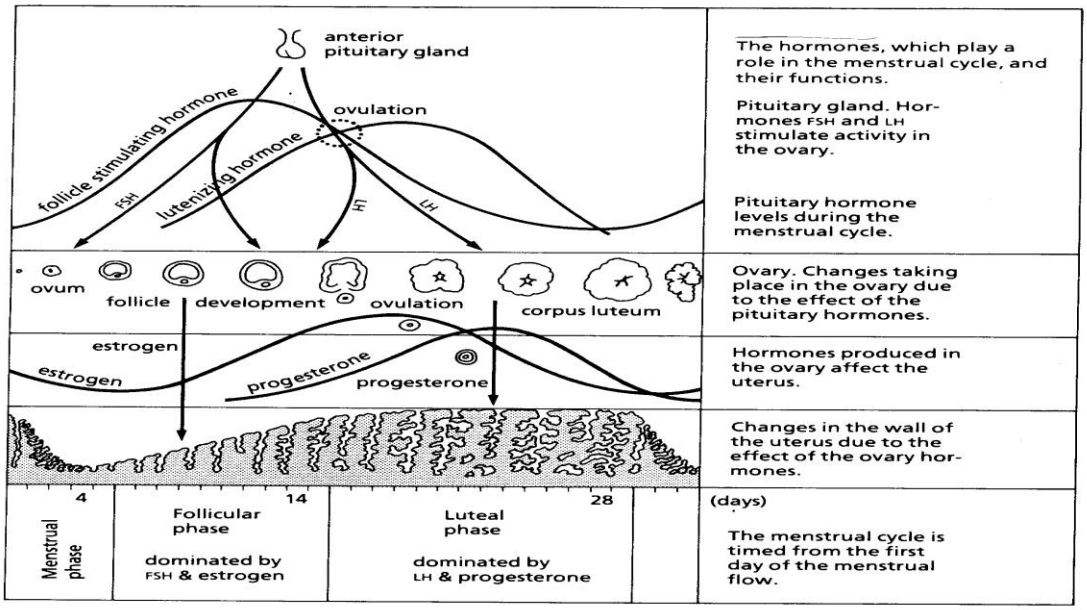


Diagram 39: The menstrual cycle phases, hormones, events, and changes.

(June 2000 MC 20) (January 1999 NR 2) (June 1999 NR 1) (June 2002 MC 17, 18) (June 2003: MC 11)

• ***identifying the principal reproductive hormones in the male and explaining their interactions in the maintenance and functioning of the male reproductive system; e.g., testosterone, luteinizing hormone (LH), follicle stimulating hormone (FSH)*** pp.492-495

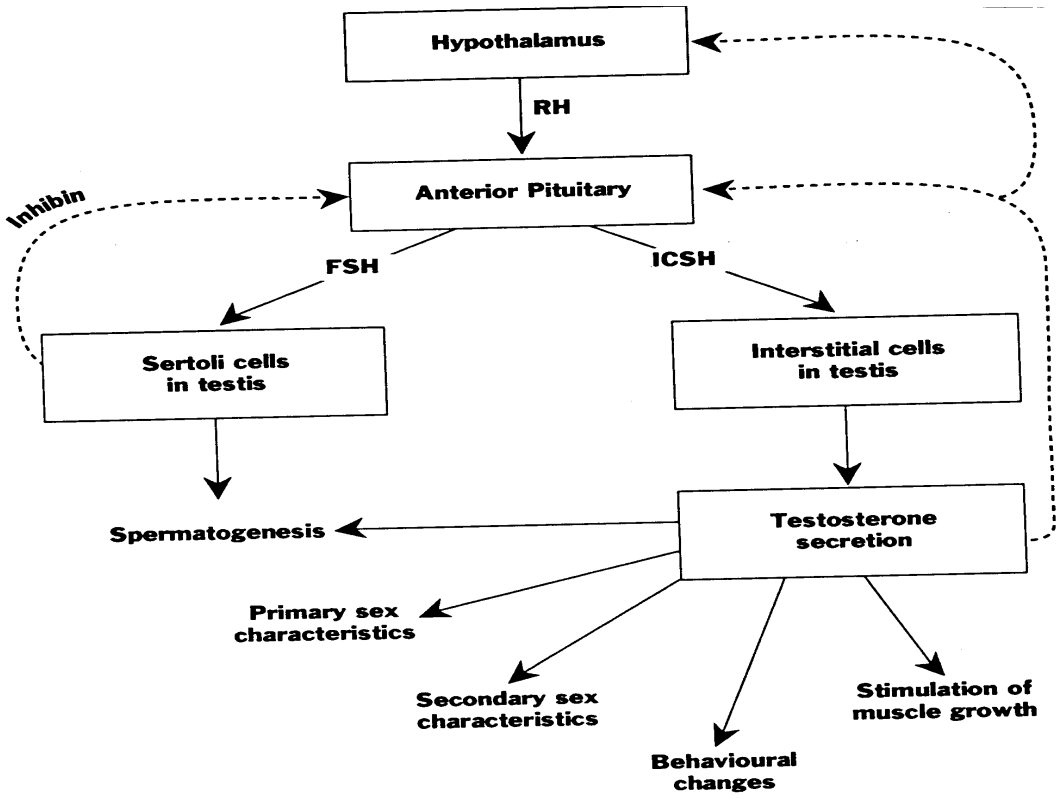
Regulation of the male reproductive system (see diagram 40)

a) Testosterone- is a hormone produced by the interstitial cells found between the seminiferous tubules inside the testes. It is produced in response to LH production by the pituitary and decreased when testosterone is too high (testosterone inhibits the pituitary production of LH and FSH). It also accelerates sperm cell development and influences secondary sex features

b) Luteinizing hormone- produced the pituitary and stimulates interstitial cells to produce testosterone. It is inhibited by high testosterone.

c) Follicle stimulating hormone- is produced by the pituitary and stimulates the sertoli cells inside the seminiferous tubules to speed up spermatogenesis. It is inhibited by inhibin. (FSH , LH are gonadotropins)

d) Inhibin- a hormone produced by the sertoli cells as they produce sperm cells. As inhibin increases it inhibits the pituitary from producing FSH.



Hormonal regulation in males. Releasing factor (RF) from the hypothalamus in the brain activates the anterior lobe of the pituitary to release follicle stimulating hormone (FSH) and interstitial cell stimulating hormone (ICSH). Inhibin and testosterone act to inhibit the secretion of FSH and ICSH respectively.)

Diagram 40: Regulation of the male reproductive system

(June 2000 NR 1) (January 1999 NR 1) (January 2001 MC 14) (January 2002 NR 3)

• ***comparing the cyclical patterns of reproduction in humans with that of nonprimate mammals.***

Menstrual cycle- is a cyclical pattern of preparation of the uterus for a fertilized egg. It is characterized by a regular (monthly) shedding of the inner uterine lining (endometrium) with the associated blood and tissue discharge from the uterus through the vagina (menstruation). This occurs in most primates to one degree or another.

Estrus cycle- is a type of reproductive cycle found in other mammals that does not involve a menstrual flow phase. Most mammals have mating seasons, usually in the fall or spring. Although the males are capable of breeding year-round, most females will mate only when they are in "heat" or estrus, during which time the ovaries release mature ova. The frequency of estrus varies from mammal to mammal: once a year for deer; every six months for dogs; every three weeks for cows, horse, and pigs; every four days for mice. During the estrus phase the females' urine contains chemicals that indicate estrus is taking place. The male can detect these chemicals often resulting in competition for breeding among males.

Hermaphrodites- are organisms that posses both male and female reproductive organs (primarily the ovaries and testes). Some can self fertilize, but most do not. Examples include earthworms.

3. Cell differentiation and development in the human organism are regulated by a combination of genetic, endocrine and environmental influences.

• ***events following conception are governed by a combination of genetic, endocrine and environmental influences, by extending from Biology 20, Unit 4, the human organism as a system, and by:***

• ***tracing the processes of fertilization, implantation, extraembryonic membrane formation (e.g., amnion, chorion, yolk sac, placenta), embryo development, parturition and lactation, and the control mechanisms of those events; e.g., progesterone, LH, chorionic gonadotropin, oxytocin, prolactin*** pp.508-519

Pregnancy/Fertilization (see diagram 41)

1. fertilization usually takes place in the upper portion of the fallopian tube (see diagram 38)
2. fertilization can only occur within a span of 24 hours after ovulation
3. most of the sperm cells die, a few thousand may meet the ovum
4. enzymes in the acrosome of the sperm cells dissolve the corona (cells) around the egg this usually requires many sperm cells
5. only one sperm cell breaks through the membrane surrounding the ovum (pellucida)
6. once a sperm cell enters the membrane changes so no other sperm cells may enter (the enzymes are unable to dissolve it further)
7. the fertilized egg is called a zygote

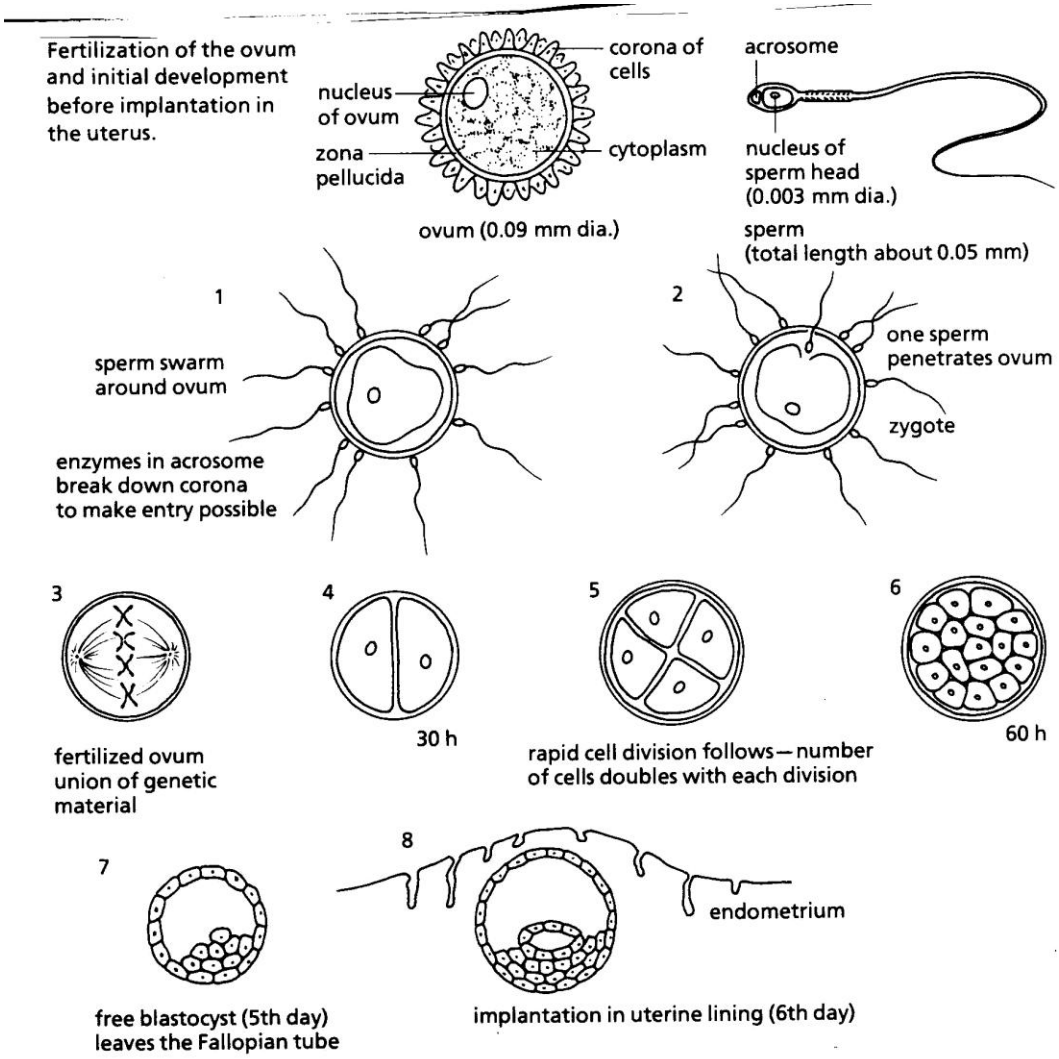


Diagram 41: Fertilization and implantation

Implantation, Extraembryonic membrane formation (see diagram 42 and 43)

1. The zygote undergoes mitosis as it travels down the fallopian tube. After the 34 hour stage a 16-32 cell solid ball of cells is formed (the morula).
2. This process continues until a hollow ball of cells, the blastocyst or blastula, develops. The inner layer of cells of the blastocyst will form the embryo. The outer cell layer will form the early embryonic membranes (chorion, yolk sac, amnion). If it attaches in the fallopian tube this is called an ectopic pregnancy and must be terminated.
3. Once the blastocyst has reached the uterus (about 6 days) implantation begins. Enzymes of the blastocyst outer layer of cells (the chorion) destroy cells and blood vessels of the endometrium. The blastocyst embeds itself into the endometrium and continues to breakdown the tissue after implantation to provide nutrients for the embryo. Ectopic pregnancies occur when implantation happens in the fallopian tube or outside of the reproductive organs.
4. Once embedded the chorion begins to produce the hormone HCG that stimulates the corpus luteum to continue producing progesterone, thus preventing menstruation from occurring and sustaining the pregnancy. The chorion is the embryonic portion of the placenta. The placenta is essential to the survival and growth of the embryo/fetus. It produces important hormones (HCG, estrogen, and progesterone). It provides the membrane surface for exchange of nutrients, minerals, hormones, antibodies, gasses and wastes between the fetal and maternal blood supplies (see diagram 44). It is also the site where many teratogens (environmental agents that induce developmental abnormalities) crossover from the maternal blood supply to the embryo/fetal blood supply.

5. The yolk sac does not supply nutrients to a mammalian embryo as it does in birds, reptiles and amphibians. It does however have several important functions. It is the early source of red blood cells before the embryo produces its own. It also will form a portion of the digestive tract, and is the source of the primordial germ cells.
6. The amnion will eventually surround the embryo, enclosing it in a fluid-filled sac. This fluid-filled sac serves several functions including: cushioning the embryo from impact to the mother, temperature control of the embryonic environment, protection of the fetus from infection, and enhancing muscle development, joint development and neural connections by allowing the fetus to move more freely.

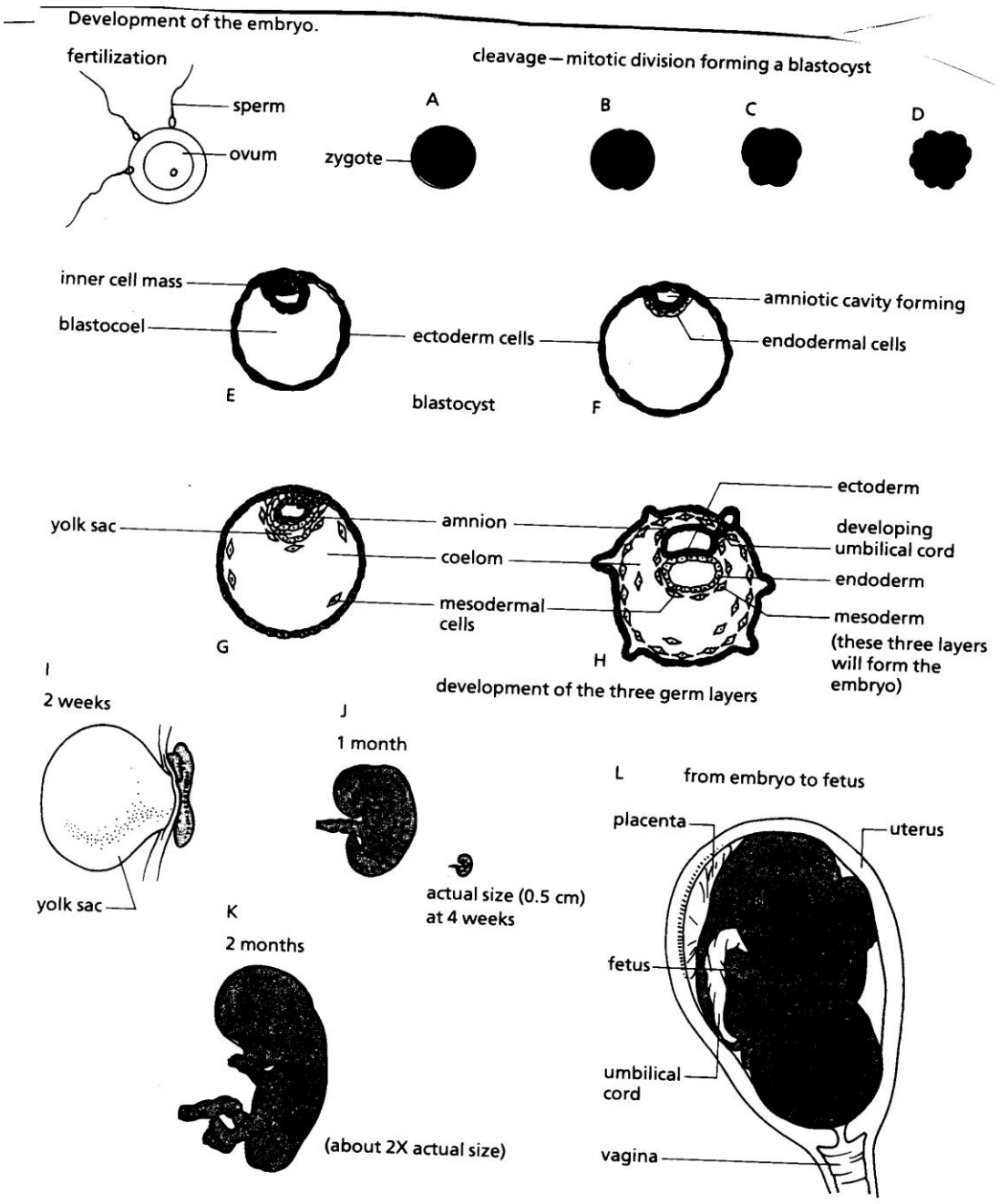


Diagram 42: Fertilization, implantation, and embryonic development

(June 2002: MC 14, 19, 20, NR3, June 2004 MC 7, Aug 2006: MC 7)

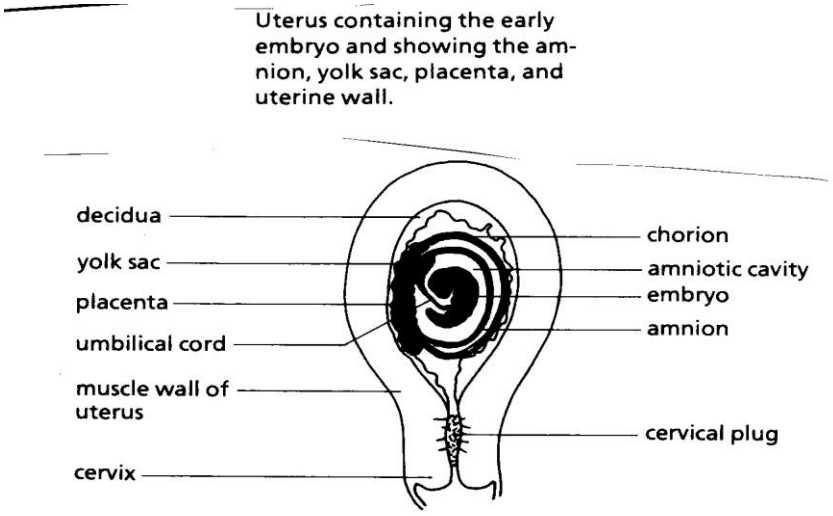


Diagram 43: The uterus and extraembryonic structures

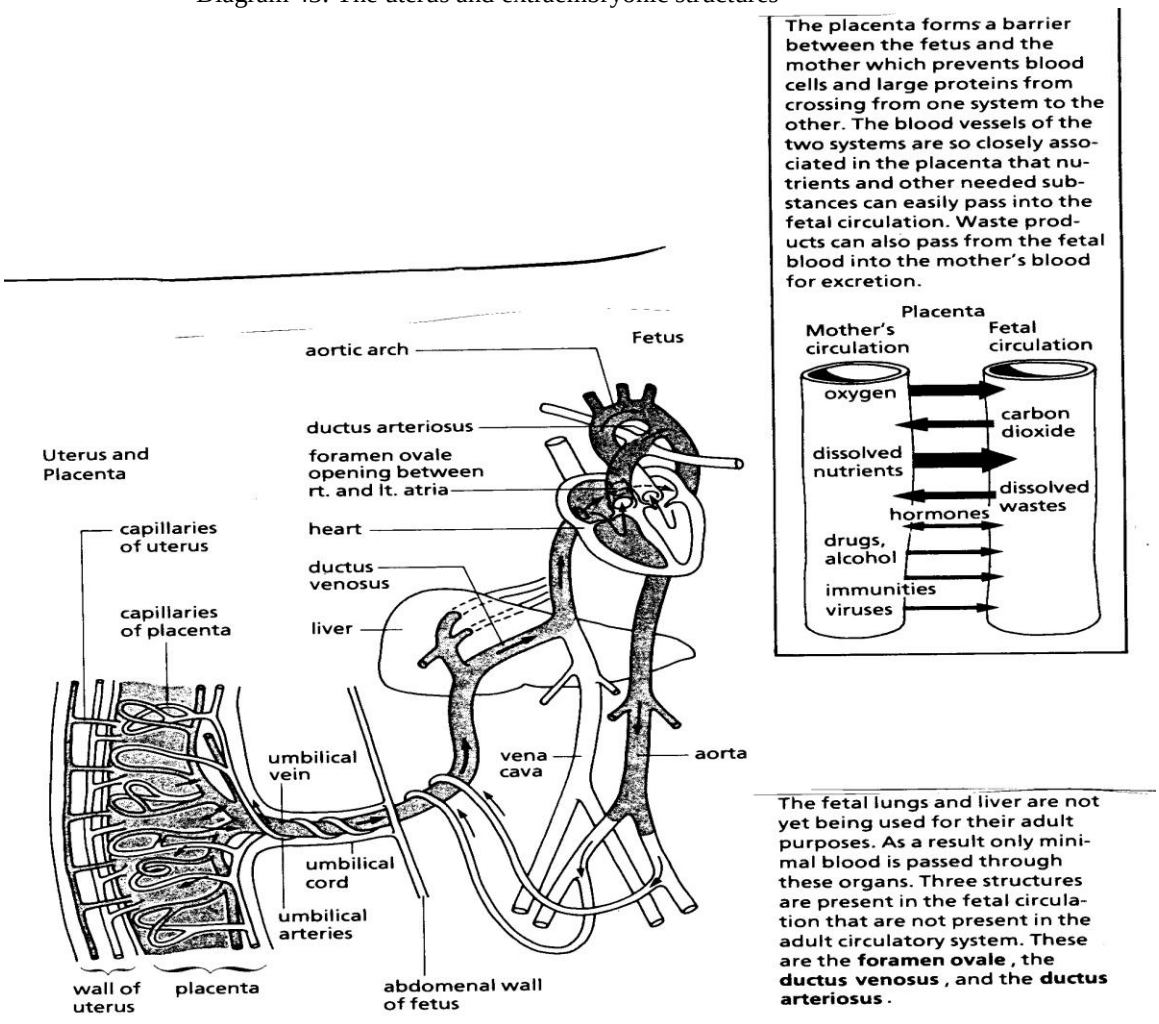


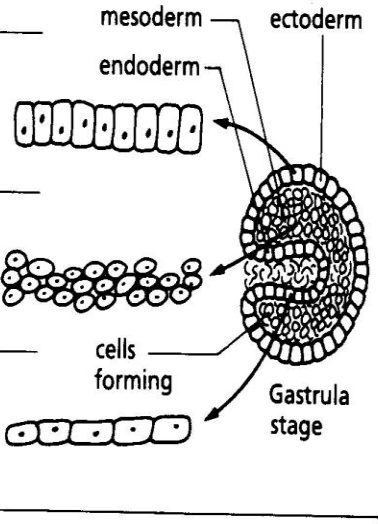
Diagram 44: The structure of the placenta and umbilical cord

(January 2000 MC 16, 17) (June 1999 MC 17) (June 2002: MC 13)

• ***describing fetal development from implantation to full term in the context of the main physiological events that occur in the development of organ systems during each major stage (trimester) and the influence of environmental factors on the development of these systems; e.g., alcohol, drugs, pathogens.*** pp.520-528

1. At the end of the third week after fertilization, the embryo has developed into a three-layered disc. This is called gastrulation.
2. These three layers give rise to the various tissues and organs of the embryo.
3. All body systems develop from the three germ layers: endoderm, mesoderm, and ectoderm (see diagram 48). The ectoderm gives rise to the epidermis (skin, hair, etc) and the nervous system, the mesoderm gives rise to the muscle, bone and blood vessels, and the endoderm gives rise to the digestive and respiratory organs.
4. At about 8 weeks all body systems are present but not fully developed, bone tissue begins to form at which point the embryo is now called a fetus. This is the name used until birth, then the fetus is called a baby (technically)
5. The period of time the embryo/fetus is developing in the uterus is called the gestation period. The development of the embryo is divided into three, three month segments called trimesters
6. After about three months the placenta is grown enough to make its own progesterone, the HCG declines and progesterone increases maintaining the endometrium, placenta, and fetus

GERM LAYER	TISSUES AND ORGANS (BY DIFFERENTIATION)
Ectoderm	Nervous system, epidermis, parts of the eye, salivary galnds, pituitary gland, adrenal medulla, skin, hair, and nails
Mesoderm	Connective tissue, bone, muscles, cartilage, blood, blood vessels, lymphatics, spleen, adrenal cortex, parts of the reproductive organs
Endoderm	Epithelium of the digestive tract, linings of the lungs and respiratory passages, liver, pancreas, thyroid, parathyroid, and thymus glands



(Aug 2006: MC 6, NR 2)

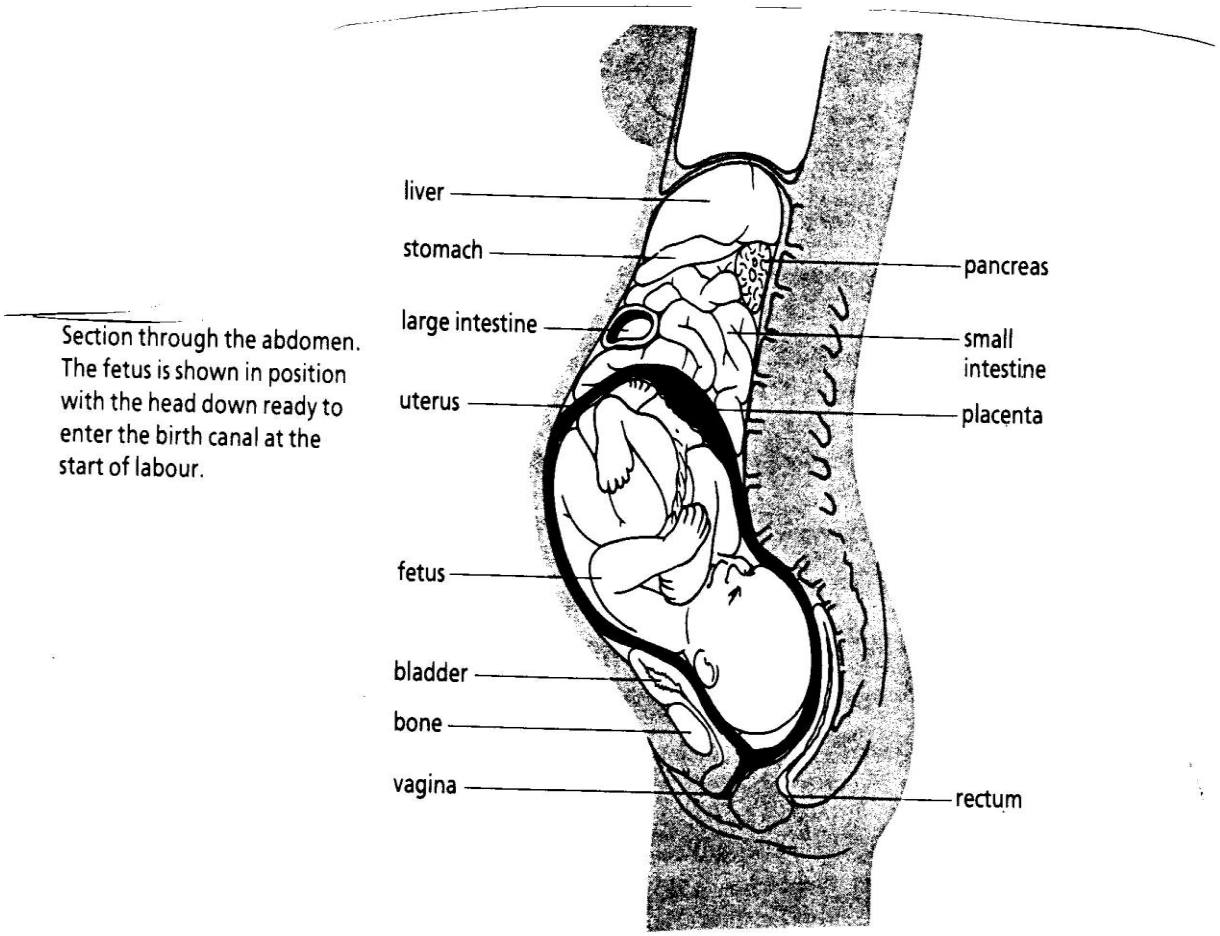
Diagram 48: The germ layers of the early embryo

Summary of fetal development over 9 months.

Trimester	Embryo/fetal development
First	From fertilization to end of the third month. Three germ layers form by second week. By fourth week the heart has formed, arms, legs, fingers, toes start to form. By end of third month arms and legs are formed and can move. Embryo is now called a fetus
Second	From third to sixth month. All organs have formed, bones form. Fetus grows from about 57 mm to 350 mm and 680 g.
Third	From sixth to ninth month. A period of rapid growth, the fetus increases in size and mass as all organs and systems become more developed. At birth the baby is on average 530mm and 3400g.

Parturition and Lactation (see diagrams 45 and 46)

1. Usually occurs around 266 days after conception (fertilization) or 280 days after the beginning of the last period
2. Birth occurs in 3 stages: dilation, delivery, and discharge of the placenta(afterbirth)
3. Dilation can take 2-24 hours during which the opening of the cervix enlarges from 0cm to 10cm (fully dilated)
4. Delivery can take from 5 – 60 min during which contractions of the uterus combine with voluntary pushing by the mother to push the baby out of the uterus (head first) and through the vagina.
5. Discharge of the placenta can take from 1 – 60min during which the uterus continues to contract to cause the placenta to be removed, this is the afterbirth.
6. Hormones used during birth are produced by the placenta, uterus, and pituitary gland.
7. Closer to birth the pituitary begins producing more oxytocin which causes contractions of the uterus. The placenta produces relaxin that inhibits progesterone production and brings about contractions of the uterus.
8. It also allows the ligaments that hold the pelvic bones together to relax allowing some expansion of the birth canal and other side effects.
9. The uterus also produces prostaglandin's that cause or intensify the contractions previous to birth (labor pains)



Section through the abdomen. The fetus is shown in position with the head down ready to enter the birth canal at the start of labour.

Diagram 45: Position of fetus at nine months (full term)

(June 2004: MC 8)

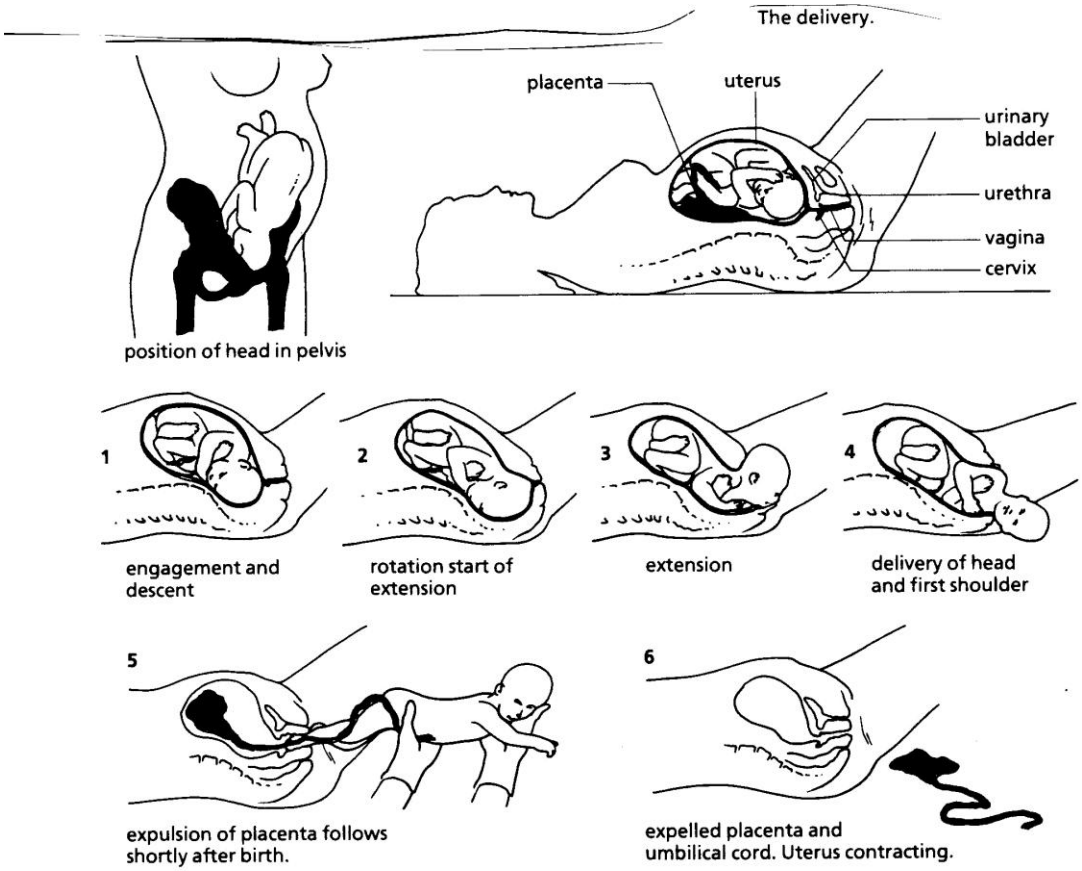


Diagram 46: Events that occur during delivery

Lactation is the process of breast feeding. As described earlier prolactin is the hormone responsible for milk production during breast-feeding. When the baby sucks on the nipple nerves in the nipple and areola send signals to the brain (hypothalamus/pituitary). The pituitary then responds by releasing prolactin and oxytocin into the blood stream causing both breasts to release milk (see diagram 47).

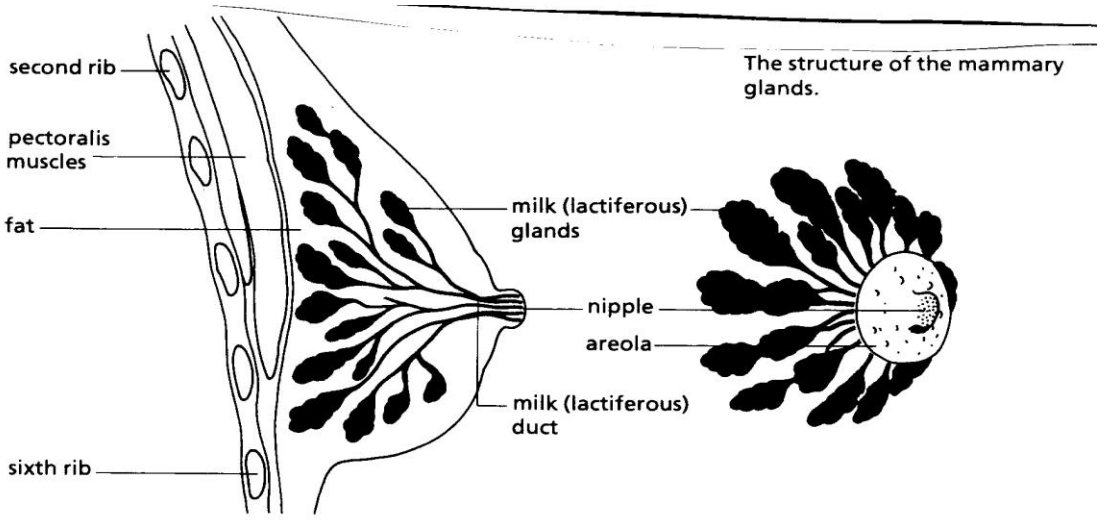


Diagram 47: The anatomy of the breast

Teratogens are environmental agents that induce developmental abnormalities in the growing embryo and fetus. Most of these are chemicals that cross over from the maternal blood into the embryo/fetal blood in the placenta.

Examples:

Teratogen	Most common congenital anomalies
Thalidomide	Limb reduction defects, ear anomalies, heart defects
Warfarin (anticoagulant)	Incomplete nasal cartilage, central nervous system defects, eye anomalies, mental retardation
Streptomycin	Hearing loss
Testosterone (high doses)	Masculinization of external female genitalia
Cigarette smoke	Pregnancy loss, low birth weight
Chronic alcoholism	Fetal alcohol syndrome, growth and developmental retardation, abnormal facial features

(January 20001 MC 20, 22, NR 2,3) (June 2001 WR 2)

• ***describing the physiological or mechanical basis of different reproductive technology methods; e.g., conception control, in vitro fertilization, infertility reversal.*** pp.529-534

In vitro fertilization-involves the fertilization of an egg outside the uterus in a petri dish. Eggs are extracted from the uterus and placed in a petri dish with sperm. The resulting embryos are transplanted into the uterus and hopefully one will implant in the endometrium
Ultrasound- the use of high frequency sound to make a picture/examine the developing fetus
Chorionic villus sampling-taking a sample of the chorion/placenta to examine the cells (of the baby) chromosomes
Amniocentesis- involves taking a sample of the amniotic fluid that contains cells of the baby. The cells are cultured (grown) so that the chromosomes can be examined (often a karyotype is produced)
Vasectomy-removing a portion of, and tying off the vas deferens to prevent passage of sperm cells only.
Tubal ligation- removing a portion of and tying off the fallopian tube to prevent passage of eggs.
Fertility drugs- usually simulate FSH and cause multiple eggs to develop in the ovaries
Birth control pills- usually simulate estrogen and/or progesterone. They inhibit the pituitary production of FSH and LH preventing any eggs/follicles from developing or being ovulated.

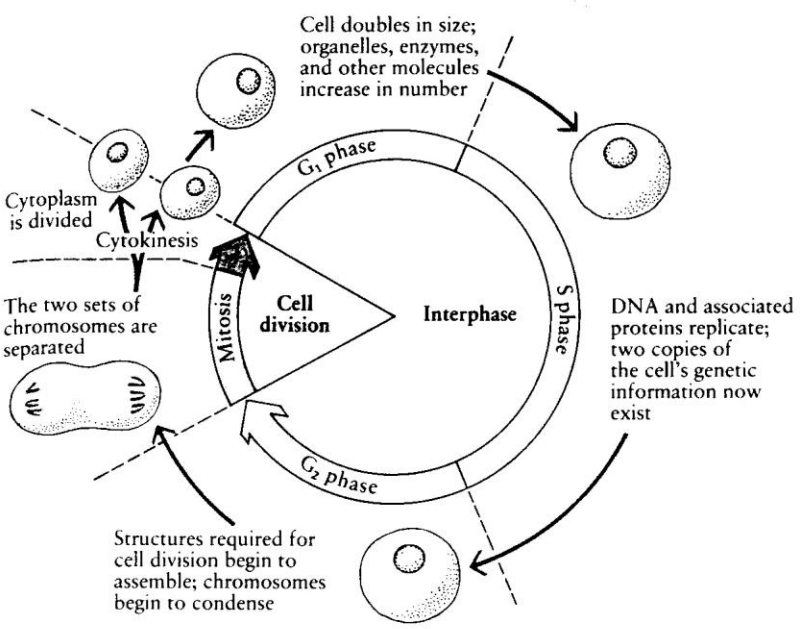
(June 2000 MC 21,22, NR 2) (January 2000 MC 14,15) (January 1999 MC 17, 18, 19)

UNIT 3
CELLS, CHROMOSOMES, AND DNA

1. Cells divide to increase in number but must reduce their chromosome number before combining at fertilization.

- ***chromosomes are duplicated before cells divide; that daughter cells get one complete set of chromosomes; that chromosome number must be reduced before fertilization; and that variations in the combination of genes on a chromosome can occur during that reduction, by recalling from Science 10, Unit 2, that growth may involve increasing cell number, and by:***
- ***explaining, in general, the events of the cell cycle, including cytokinesis, and chromosomal behaviour in mitosis and meiosis.***

The Cell Cycle (see diagram 49) pp. 550-555



The cell cycle. Cell division, which consists of mitosis (the division of the nucleus) and cytokinesis (the division of the cytoplasm), takes place after the completion of the three preparatory phases (G_1, S, and G_2) that constitute interphase. After the G_2 phase comes mitosis, which is usually followed immediately by cytokinesis. In cells of different species or of different tissues within the same organism, the different phases occupy different proportions of the total cycle.

Diagram 49: The cell cycle

The cell cycle is described in two parts: Interphase and cell division (or mitosis). Interphase occupies most of the cells life cycle and subdivided into three sections G-1 phase, S phase, and G-2 phase

Stages of Interphase	Characteristics
Gap 1	Cell growth, protein synthesis, normal cell functions, about 11 hours
S phase (synthesis)	DNA replication, up to 7 hours
Gap 2	Cell growth, protein synthesis, 4 hours

Cell division is divided into two parts mitosis and cytokinesis. pp.556-561

1. Mitosis is the process by which cell division normally occurs in most body cells(exceptions include muscle and nerve cells and cells in the ovaries and testes). It is often called asexual cell division since it involves only one parent cell. Its purpose is to equally divide the chromosomes so the new cells have exactly the same chromosomes, therefore are identical (called daughter cells). These cells are used for growth or replacement of dead or damaged cells. Mitosis occurs in 4 distinct stages.

Stages of Mitosis (see diagram 50)

Stages of Mitosis	Characteristics
Prophase	Nuclear membrane breaks down, spindle fibers begin to form, chromosomes condense
Metaphase	Spindle fibers formed and attach to centromeres, chromosomes line up across equatorial plate
Anaphase	Chromatids segregate (separate) and move to opposite spindle poles
Telophase	Nuclear membrane reforms, chromosomes disappear, cytokinesis occurs

2. Cytokinesis involves the equal division of the cytoplasm between the two daughter cells. The parent cell has now split into two new daughter cells, each cell has the same number of chromosomes as the parent cell (this is called the diploid number of chromosomes)

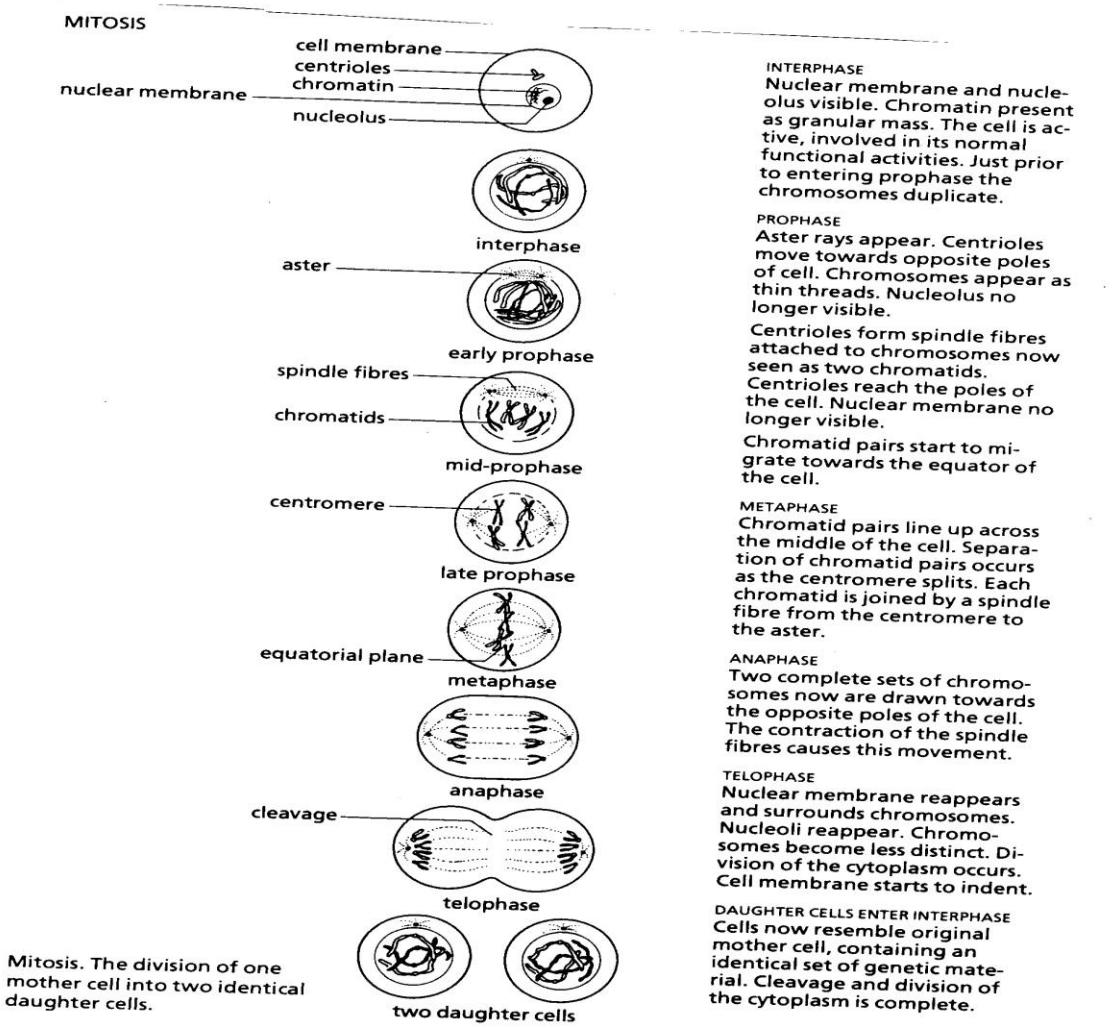


Diagram 50: The stages of mitosis

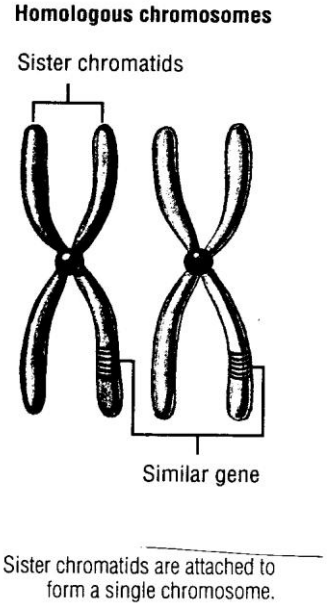
DNA	A strand of nucleotides composed of a double helix structure. DNA makes up the chromatin, chromosomes or chromatids.
Chromatin	Strands of genetic material (DNA) that are unraveled into long thin strands during interphase. Found during the resting phases of the cell's life cycle
Chromosome	Thick shortened strands of genetic material (DNA) Noticeable just before cell division (condensed)
Chromatid See diagram 51	Replicated chromosomes that are attached at the centromere. Chromatid pairs are found during cellular division (metaphase of mitosis and meiosis)
Nucleolus	Used in the synthesis of ribosomes
Spindle fibers	Protein strands that attach to the centromere and pull the chromatids to opposite ends of the cell
Centriole	Found in animal cells only. They provide attachment for spindle fibers
Centromere	The spot, usually in the middle, on the chromosome where the spindle fibers attach. This spot holds the two sister chromatids together.

(June 2000 M.C. 30, 31, June 2002: MC 22)

Regulation of cell division.

The purpose of cell division is to replace dead or damaged cells, and for growth. Not all cells divide. Muscle cells and brain cells do not divide. You are born with a fixed number of both muscle and nerve cells. Of the cells that do divide division happens only when there is a stimulus to divide. Examples of stimuli would be damage to neighboring cells (bruises, cuts, or burns), hormone signals (GH, thryroxine), or genes within the cell that tell it to divide at certain times. As we live our lives, our cells keep dividing to replace old, dead cells. But cells can only divide so many times. As they slow down and stop, our bodies are less able to repair damage and are more at risk for disease. This is how we get old. Aging is also partly caused by telomeres. Telomeres are repeated sections of DNA on the ends of the chromosomes. Each time a cell replicates its chromosomes (for cell division) its telomeres wear down (get chopped shorter). When they get too short the cell cannot divide any more. Some cells in the body, such as sperm and egg cells and stem cells, contain the enzyme telomerase. This enzyme repairs telomeres so they do not get shorter with each replication. This allows these cells to divide indefinitely.
January 2001 M.C. 36

Diagram 51: Chromatids in chromosomes



Stem cells: are cells that have the ability to divide over and over again to form the specialized cells, tissues and organs that make up our body. They have complete, identical sets of chromosomes.

Totipotent stem cells: Are cells that have the ability to develop into any of the 210 cells including extraembryonic membranes. They have not specialized yet. They are undifferentiated stem cells. After the 16-32 cell stage in humans the cells are no longer totipotent, they begin to specialize.

Pluripotent stem cell, embryonic stem cells: are cells that have the ability to form all cells, tissues and organs in the body except the extraembryonic membranes.

Committed stem cells/ Adult stem cells: are specialized cells such as nerve cells in the brain, or blood cells in the bone marrow, that are unique to the organ and can only develop into more specialized cells of that same organ. Some adult stem cells in the lab have been made to differentiate into a wider range of cell types than they normally do in the organism.

Cancer- is a group of disorders that occur when cell division becomes uncontrolled. This often results in the formation of many immature (young) cells that have too many chromosomes and therefore are nonfunctional. If the cells continue to divide at faster than normal rates they form an area of dense tissue, or a lump/tumor. The tumor may be malignant or benign. The malignant tumors are the actual "cancerous" tumors that are composed of nonfunctional cells, and may spread to other areas of the body, called metastasis. The benign tumors have functional cells and are therefore classified as noncancerous.

Stages of Meiosis or Sexual cell division pp.563-571 (see diagram 52)
Meiosis is another form of cell division that only occurs in the ovaries and testes. Its purpose is to produce gametes, or sex cells (sperm and egg produced by different parents defined as male for sperm and female for eggs) that have half the chromosome number. These cells are called haploid while the parent cell that gives rise to them is still diploid. Whereas mitosis involves only one division of the parent cell (somatic cell), meiosis has two divisions (see diagram 55). The first division reduces the chromosome number in half while the second division only produces more cells, so the second division is identical to the stages in mitosis.

Stages of meiosis	Characteristics
Prophase I	Nuclear membrane disappears, chromosomes condense, become visible, homologous chromosomes pair up (synapsis) forming a tetrad, crossing over occurs here. Homologous chromosomes are chromosomes that have similar shape, size, and genes
Metaphase I	Homologous chromosomes (see diagram 51) line up randomly on the equatorial plate, spindle fibers attach to the centromere
Anaphase I	Chromosome pairs move to opposite poles of the cell in a process called segregation. The chromatids do not separate a the centromere
Telophase I	Cytokinesis occurs forming two cells with half the number of chromosomes as the parent cell, nucleus forms around the chromosomes
Prophase II	Spindle fibers form, nuclear membrane disappears
Metaphase II	Chromosomes line up at equatorial plate, spindle fibers attach to centromeres
Anaphase II	Spindle fibers pull chromatids apart and chromatids/chromosomes move to opposite poles of the cell
Telophase II	Nuclear membrane reforms around chromosomes, cytokinesis occurs producing two haploid cells from each cell.

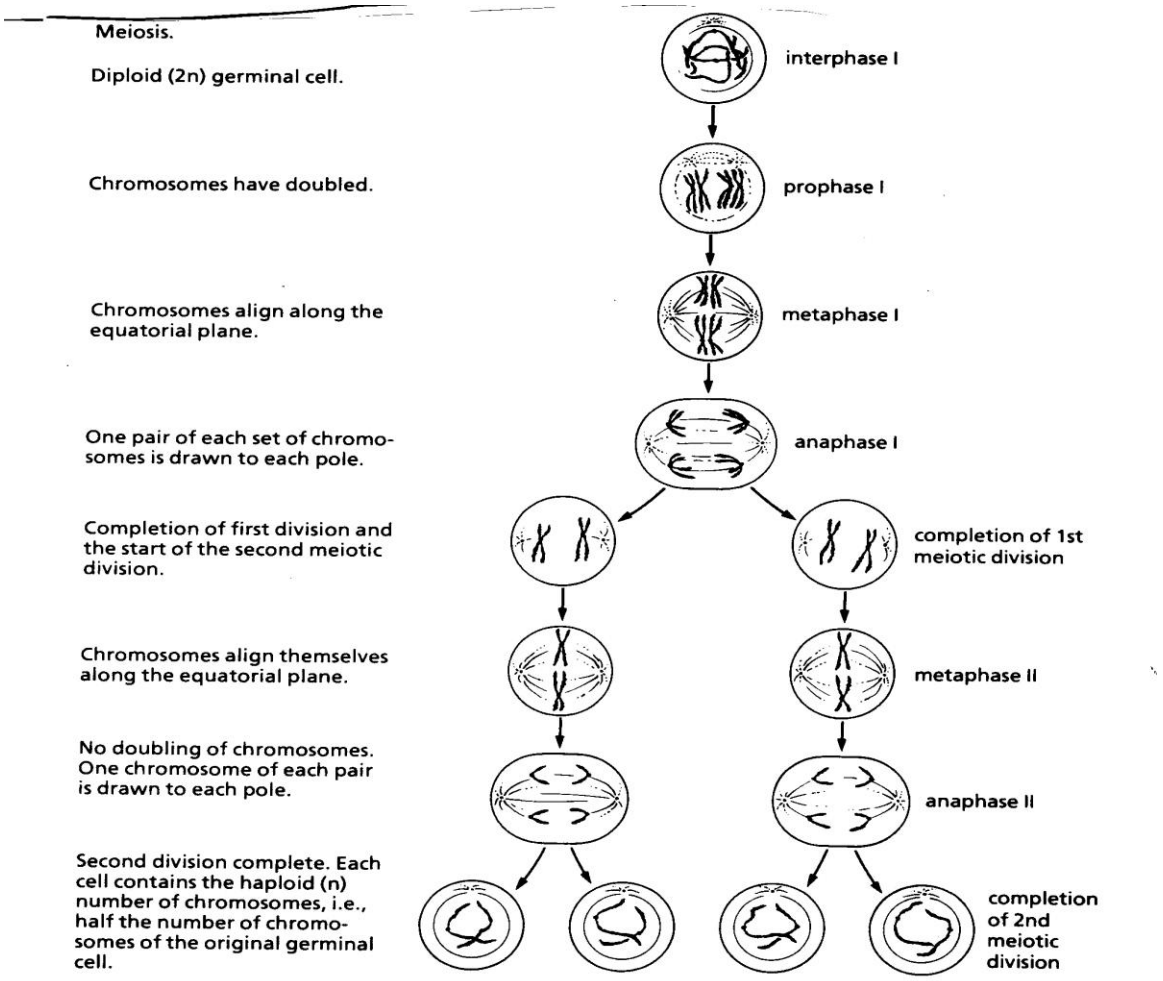


Diagram 52: The stages of meiosis

Necessity for chromosomal reduction
The production of haploid cells in meiosis (reduction division) is necessary to ensure the proper chromosome number is restored every time fertilization occurs. Haploid cells also allows for variation in offspring through sexual reproduction. If haploid cells were not produced, every time fertilization occurred the chromosome number would double. Cells with too many chromosomes usually do not develop.
January 2000 M.C. 24

• ***describing the processes of spermatogenesis and oogenesis and the necessity for chromosomal number reduction in meiosis*** pp.563-571 (569)

Oogenesis- is the production of egg cells (ova/ovum) in the ovary.
- is stimulated by FSH from the pituitary gland
- high estrogen and progesterone from the ovary (follicle and corpus luteum) inhibit FSH and oogenesis
- it produces 4 cells, 1 larger egg cell (ovum) and 3 smaller cells (called polar bodies) that die
- usually only the ovum is released during ovulation (see diagram 53).

Spermatogenesis- is the production of sperm cells in the testes.

- This involves meiosis in the seminiferous tubules
- Results in the formation of four small sperm cells (from one parent cell) that mature in the epididymus with millions of other sperm cells.
- Sperm cell production occurs best a few degrees below body temperature, consequently the testes are contained outside the abdominal cavity in the scrotum (see diagram 53).
- FSH stimulates spermatogenesis inside the seminiferous tubules
- Testosterone speeds up spermatogenesis

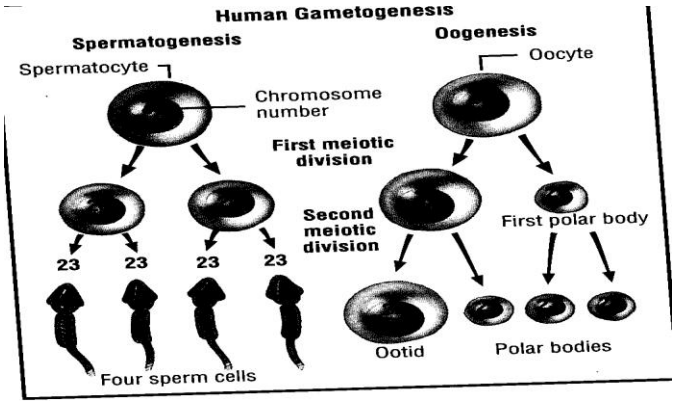


Diagram 53: Comparison of spermatogenesis and oogenesis

• describing the processes of nondisjunction and crossing over; and evaluating their significance on organism development pp.567-568

Nondisjuction

This occurs when the homologous chromosomes do not separate in anaphase I of meiosis, or when the chromatids do not separate in anaphase II of meiosis. This results in one gamete getting both chromosomes of the pair and the other gamete getting none of the chromosomes of that pair. After meiosis is complete two gametes will have an extra chromosome (in humans 24) and two gametes will lack a chromosome (in humans 22). If one of these gametes should fertilize a normal gamete the resulting individual will have an extra chromosome (trisomy), or lack a chromosome (monosomy). The effects are categorized as 'syndromes'. The most common syndrome is Down syndrome caused by an extra chromosome number 21 (the individual has 3 of chromosome 21 instead of the normal 2 chromosomes).

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January 2002 MC. 19

Karyotype

This is a chart of the pictures of all the chromosomes, arranged in order from longest to shortest, of a organism. The human karyotype has 4 rows of 23 pairs of chromosomes (46 chromosomes in all), 44 or 22 pairs are called autosomes and 2 chromosomes or one pair are called sex chromsomes.

Crossing Over (see diagram 54)

This occurs during prophase I of meiosis. When the homologous chromosomes pair up the chromatids of the different chromosomes in one pair will exchange parts (genes). The significance of this is it adds more variation to the population by producing individuals with new combinations of characteristics. There may be a survival advantage to these variations especially if the environment is constantly changing. New variations will give the population a better chance of surviving by providing adaptations to the new environment.

Chiasmata: the X like structure produced when homologous chromosomes exchange genetic material through crossing over.

Bivalent: the two chromatids of the replicated chromosome

Bivalents: the two homologous chromosomes; they form a tetrad during synapsis. There are 23 bivalents or 23 homologous chromosomes.

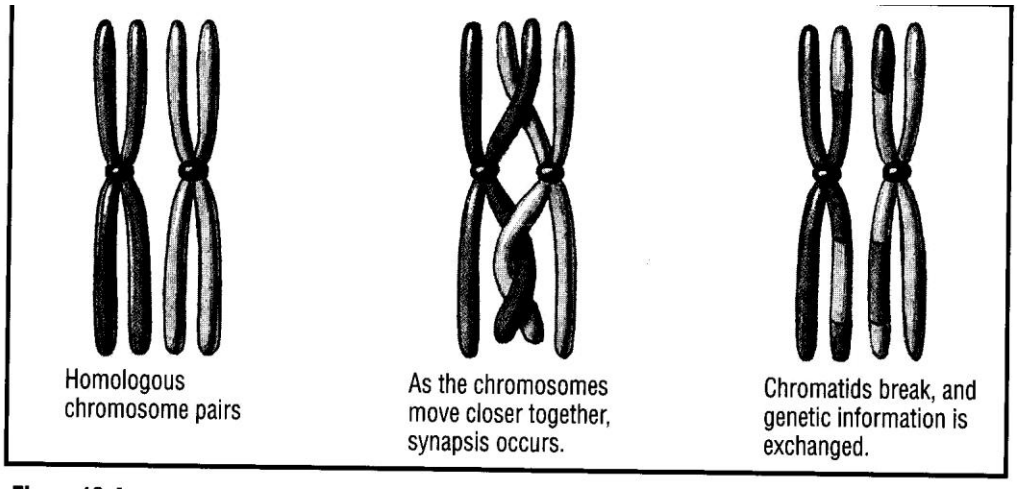


Diagram 54: Crossing over

- ***comparing the processes of mitosis and meiosis***

Comparison of mitosis and meiosis (refer to diagram 55)

Mitosis	Meiosis
Produces body cells (somatic)	Produces sex cells (gametes, sperm and egg)
Homologous chromosomes line up independently along the equatorial plate during metaphase	Homologous chromosomes line up together along the equatorial plate (synapsis) forming four chromatids (called a tetrad) during the metaphase I
Occurs in all locations of the body (somatic cells)	Occurs only in the gonads
One nuclear division per cycle	Two nuclear divisions per cycle
Chromosome pairs replicate before mitosis	Chromosome pairs replicate before meiosis
Two identical cells from one parent cell	Four cells from one parent cell
Diploid cells produces from diploid parent	Haploid cells produces from diploid parent
Daughter cells are capable of further divisions	Gametes are not capable of further division
Genetic content of cells is identical	Genetic content of cells is scrambled (crossing over)

January 2002 M.C. 17,37, 38

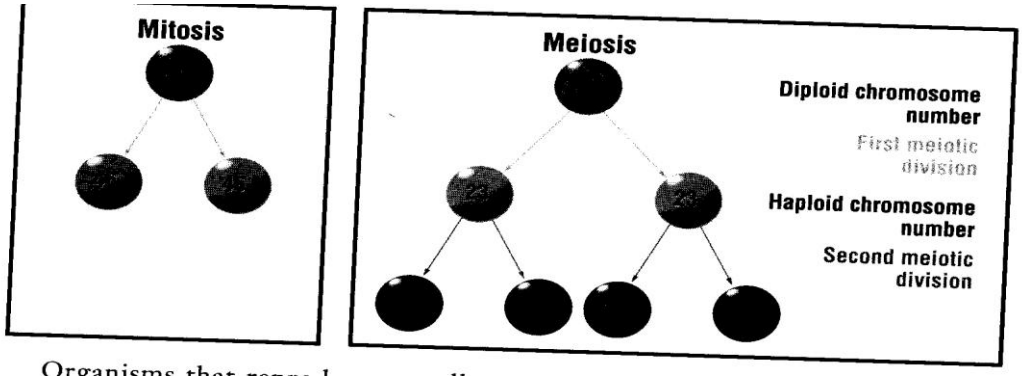


Diagram 55: Comparison of mitosis and meiosis

• ***comparing the formation of fraternal and identical offspring in a single birthing event*** pp.570

Identical twins(see diagram 56)
Produced from one fertilized egg that divides abnormally, in early development usually before the blastocyst stage, to produce two separate embryos. The twins are identical in every way.

Fraternal twins(see diagram 56)
Produced when two separate eggs are ovulated and fertilized by separate sperm cells. They will each implant separately producing separate placentas. The twins will not be identical.

June 2001 M.C. 40

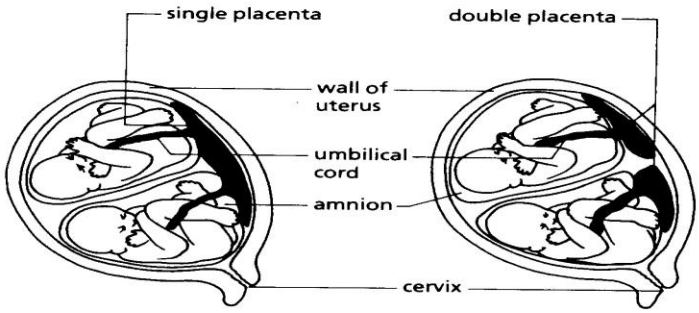
TWINS

There are two kinds of twins, those that arise from one egg and those that result from two eggs.

Sometimes, instead of the usual single ovum being released from an ovary, two are released together. As they are separate cells, they must be fertilized by different sperm. The only ''twinning'' involved in such a case is that the embryos develop in the uterus at the same time. With respect to being similar, they have no greater chance of sharing characteristics than do any pair of children with the same parents. Twins that result from two different ova are known as **fraternal** twins or dizygotic twins (two zygotes).

Identical twins, or monozygotic twins, develop from a single egg fertilized by a single sperm. The fertilized cell splits into two at a very early stage after fertilization, and each part then develops into separate individuals. These two persons, arising initially from the same ovum and sperm, contain the same genetic information and so will have all their genes in common. Identical twins will always have the same sex, either two boys or two girls. Fraternal twins may be of different sexes.

Usually twins are raised in the same home and experience the same environment throughout their growing years. Such similarity of food, care, medical attention, affection, homelife, and other factors usually results in a considerable resemblance in behaviour as well as physical characteristics. Studies of twins that have been raised separately in different homes and situations show that some differences can be produced. Such results help to distinguish between genetic and environmental influences on the growth of individuals. For example, one set of identical twins may have the genetic potential to reach a certain height. If one is raised in an environment in which good nourishment is available, this maximum height will likely be attained. If the other twin is raised in an environment with an inadequate diet, it is probable that, regardless of the genetic potential, the child will not be as tall.



Identical twins develop from a single ovum, fertilized by a single sperm. Identical twins share the same genetic characteristics and are always of the same sex.

Fraternal twins develop from two different ova fertilized by two different sperm. They have no more genetic characteristics in common than ordinary brothers and sisters. Fraternal twins are not necessarily the same sex.

Diagram 56: Identical and fraternal twins

• ***describing the diversity of reproductive strategies by comparing the alternation of generations in a range of plants and animals; i.e., pine, bee, mammal.*** Pp.573-580

<u>Sexual reproduction</u>
Involves different sexes of a species producing gametes that unite to produce and embryo that grows into a new individual. Fertilization can happen externally, as in fish, or internally, as in birds and mammals. The embryo can grow internally in a uterus, or externally in an egg. There are many variations of these strategies.

Asexual reproduction
Involves one member of a species cloning itself. No gametes are required. Examples of this include runners in strawberries and poplar trees, and binary fission in bacteria.
Binary fission
A form of asexual cell reproduction in which the parent organism splits in half to form two new (diploid) individuals
Parthenogenesis
This involves the development of an organism from an unfertilized egg. Dandelions, some fish and lizards, as well as many insects perform this.
Alternation of generations(see diagram 57)
This involves the cycling between diploid and haploid stages within the life cycle of sexually reproducing plants. There are various forms of this process throughout the living world. The amount of time spent in a particular stage depends on the species and the environment of that species. Many plants use this method of reproduction. They can exist in two different forms. A diploid body form called the sporophyte and a haploid body form called the gametophyte. The sporophyte produces haploid cells (spores) (which are very resistance/hard and are an adaptation to difficult environments or conditions) that will grow into a gametophyte. The gametophyte in turn will produce haploid gametes which will fertilize with other gametes to produce a new sporophyte plant.

January 2001 N.R. 5 June 2002: MC 44 Aug 2006: MC 8,9
January 2000 M.C. 23 June 2003: MC 1,2,3

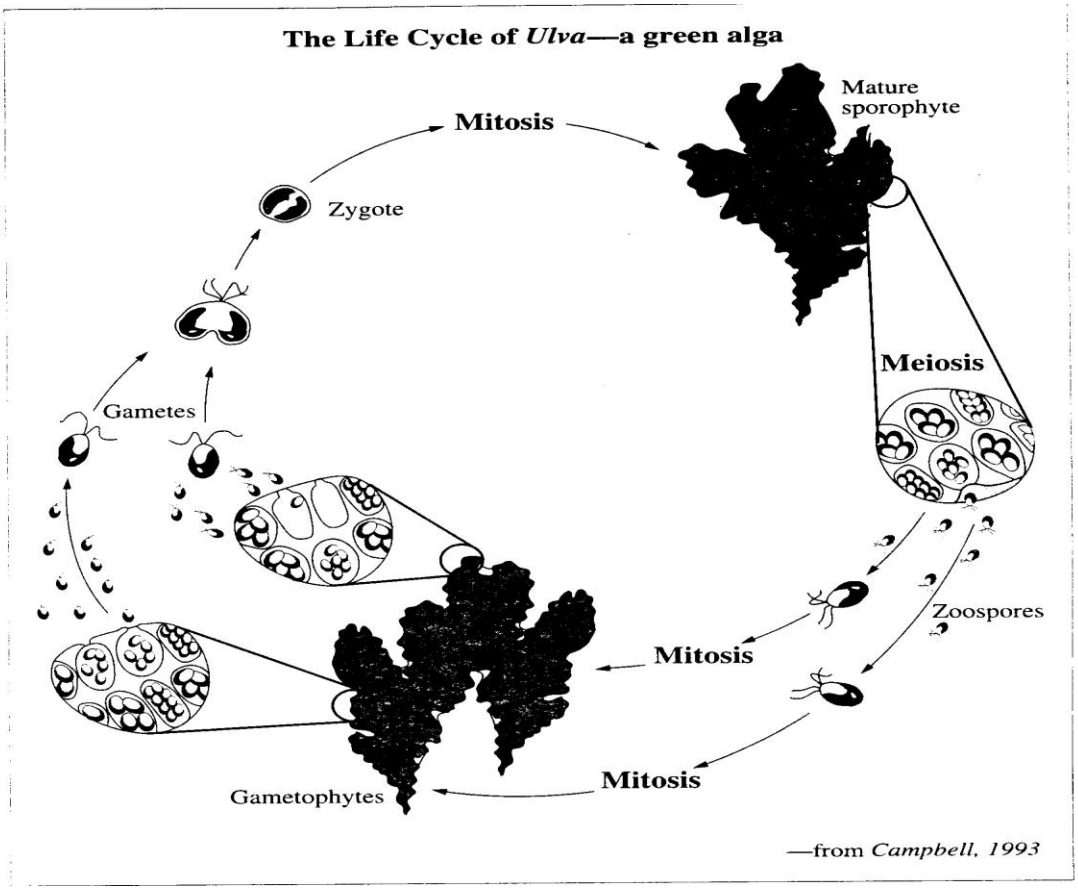


Diagram 57: Alternation of generations

2. Genetic characters are handed down by simple rules.
- ***chromosomes consist of a sequence of genes and their alleles, and that during meiosis and fertilization these genes become combined in new sequences, by extending from Biology 30, Unit 2, fertilization and development in the human organism, and by:***
- ***describing the evidence for the segregation of genes and the independent assortment of genes on different chromosomes, as investigated by Mendel*** (pp.586-598)

Hereditary characteristics: traits determined by genes carried on chromosomes passed from parents to offspring

Acquired characteristics: characteristics received from the environment and are not passed on to offspring, they do not affect the genes.

Gregor Mendel's four laws of inheritance:
An Austrian monk Gregor Mendel started the analytical study of genetics. Mendel worked mostly with pea plants so the first examples we will use will follow some of the crosses he used to establish the first "laws" of inheritance.

First Law: The Law of Parental Equivalence
Each characteristic is determined by at least two genes (we will use the term genes here even though Mendel did not know of these. Genes and chromosomes were discovered much later. The different forms of the gene are called alleles. Mendel used the term 'factors' to describe this unit of heredity). One gene comes from each parent.

Second Law: The Law of Dominance
The different forms of a gene are called alleles. One form of the gene is often dominant while the other form of the gene will then be recessive. When paired together the dominant allele is the one expressed (that is why it is called dominant) while the recessive allele is not expressed but still carried by the individual. The recessive allele can only be expressed if the other allele is also recessive. The different combinations of alleles are called genotypes while what these combinations physically look like are called phenotypes. There are specific names given to these combinations of alleles or genotypes. Homozygous dominant (h. dom) is when both genes are the dominant allele. Heterozygous or hybrid (hetero) is when one gene is the dominant allele and the other gene is the recessive allele. Homozygous recessive (h. reces) is when both genes are the recessive allele. When writing genotypes the convention is to use the upper case form of the first letter of the dominant allele to express the dominant allele and the lower case form of the first letter of the dominant allele for the recessive allele. Using Mendel's peas: yellow seeds are dominant to green seeds therefore the alleles for seed color are:Y=yellow and y=green. The genotypes for seed color are: h. dom = YY hetero = Yy and h.reces = yy. The dominant allele is always written before the recessive allele of the same characteristic in any genotype. The phenotypes (what the genotypes are expressed as, what the seeds look like) are: YY and Yy are yellow, and yy is green

January 2002 NR 5 Aug 2006: NR 3
January 2002 MC 28, 32
Third Law: The Law of Segregation
During meiosis/gamete formation the chromosomes separate to produce cells with half the chromosomes, one from each pair of chromosomes. Once again Mendel did not use these terms, he called chromosomes, genes, alleles 'factors'. In addition the process of meiosis was also not known at his time.

Fourth Law: The Law of Independent Assortment
Each gamete receives one chromosome from each pair during meiosis. The chromosomes separate independently of all the other chromosomes. If each pair of chromosomes was labeled a and b then the gametes do not get only the a chromosomes or b chromosomes (23 a's or 23 b's). The gametes each get a combination of a's and b's resulting in a different combination of chromosomes in each gamete.

June 2002: MC 34

Single trait crosses (monohybrid crosses)

To perform crosses all four of Mendel's laws are used to draw punnett squares. Punnett squares are tables drawn to predict the possible offspring from a cross between two individuals. It is a diagram that represents all possible fertilizations between sperm cells from one parent and egg cells from the other parent. In monohybrid crosses there will only be two different types of sperm cells and two different types of egg cells since we are only dealing with characteristics (genes) that are determined by two different alleles. Both the genotype and the phenotype of the offspring can be predicted and expressed as ratios or percentages of the total offspring. Once again these are only the predicted outcomes, the actual offspring phenotypes and genotypes and their ratios could deviate slightly from this prediction but not significantly. If there is a significant difference in the actual versus the predicted offspring then other types of gene interactions are influencing the inheritance pattern. These other interactions will be examined later. When doing crosses always use the following problem solving method.

1) State what the alleles mean, assign letters to the dominant and recessive alleles.
2) Identify the parent cross in words and after in genotype symbols.
3) Identify the gametes from each parent and set up the punnett square.
4) Interpret the genotypes and phenotypes from the punnett square and answer the problem.

In any punnett square the possible alleles, for the characteristic being examined, (in the gametes) for one parent are written across the top, above the columns, and the possible alleles, for the same characteristic, from the other parent are written to the left of the rows. An example follows.

Suppose in pea plants tall is dominant to short for the height of the plant. The possible alleles in the gametes can only be tall (T) or short (t). The cross or punnett square is set up as follows:

1) Alleles T=tall t=short
2) Parent cross: heterozygous tall X heterozygous tall
   Tt X Tt

3)

Gametes from one parent ← gametes from other parent

	T	t
T	TT	Tt
t	Tt	tt

Matching the alleles (letters) together in each box of the table (punnett square) performs the cross, each of the top letters matched to each of the letters on the side.

(June 2004 MC 11, 12, 13)

4) The result can then be interpreted as either a genotype ratio, in this case ¼ or 25% TT or homozygous dominant, 2/4 or ½ or 50% heterozygous, and ¼ or 25% homozygous recessive, or it can be interpreted as a phenotype ratio: ¾ or 75% tall and ¼ or 25% short. The offspring produced here are called the F_1 (first filial) generation. If these offspring are crossed with themselves it produces the F_2 generation.

Variations of the single trait cross:

a) incomplete dominance

This occurs when neither allele for a characteristic is dominant (both alleles are equal). The heterozygous individual expresses neither of the phenotypes of the two alleles it is composed of but expresses a new intermediate phenotype. Example: flower color of snapdragons is incompletely dominant with red, white and pink in the hybrid individual.

1) Alleles: Red=R, white=W, pink=RW.

2) Parent cross: pink snapdragon X pink snapdragon
   RW X RW

3) gametes from one parent = R , W and from other parent = R , W

	R	W
R	RR	RW
W	RW	WW

4) Genotype ratio=1:2:1 25% h. red, 50% hetero, 25% h. white.
Phenotype ratio=1:2:1 25% red, 50% pink, 25% white

b) codominance

This occurs when both alleles are dominant (again, both alleles are equal). In this case both alleles get expressed in the heterozygous individual producing mixed phenotype. Example: coat color is shorthorn cattle: Red=R, White = W, Roan = RW this is a mixture of both red and white hairs in the coat giving the animal a reddish grey blotchy coat.

1) Alleles: Red=R, White = W, Roan = RW
2) Parent cross: Red shorthorn X White shorthorn
RR X WW
3) gametes R and W

	R	R
W	RW	RW
W	RW	RW

4) Genotype ratio= 100% RW (hydrid)
Phenotype ratio= 100% roan

c) multiple alleles (pp.604)

This occurs when there are more than two alleles for a characteristic. Consequently there can be more than two phenotypes. The most common example of multiple alleles is blood type in humans. Blood type in humans also has the added variation of expressing codominance among two of the alleles: the alleles are A,B, and O (named after the presence of a specific type of protein A or B, or the absence of this protein O). A and B alleles are codominant and the O allele is recessive to both A and B. The phenotypes and genotypes are: Type A blood AA or AO, type B blood BB or BO, Type AB blood is only AB genotype, and type O blood is only OO genotype.

1) Alleles: A=type A, B=type B, O=type O, A and B are codominant
2) Parent cross: Type A heterozygous X Type B heterozygous
AO X BO
3) gametes A and O from one parent, B and O from the other parent

	A	O
B	AB	BO
O	AO	OO

4) Genotype ratio=1:1:1:1 25% for each of AO, BO, AB, and OO
Phenotype ratio=1:1:1:1 25% for each of types A,B, AB, and O bloods

Note: Another form of notation for blood type uses the capital I with a superscript A = A allele, I with a B = B allele, i = O allele

d) testcross

This is a special cross performed to determine if the genotype of a parent with the dominant phenotype is homozygous dominant or heterozygous. The parent with the unknown genotype is crossed with a homozygous recessive individual and the offspring are examined. If any homozygous recessive individuals are produced by the cross then the parent in question must be heterozygous (see example 1 cross). If the parent in question does not produce any offspring with the recessive phenotype (after repeated crosses) then the parent is homozygous dominant (see example 2 cross)

Example 1: if unknown parent is heterozygous

1)Alleles: tall=T short=t

2) Tall X short
Tt X tt (testcross)

3) gametes T and t from one parent, and t from the other parent

	t	t
T	Tt	Tt
t	tt	tt

4) Phenotypes: 50% dominant (tall) and 50% recessive (short)

Example 2: if unknown parent is homozygous dominant

2) TT X tt (testcross)

3) gametes T from one parent and t from the other parent

	t	t
T	Tt	Tt
T	Tt	Tt

4) Phenotypes: 100% dominant (tall) no recessives produced..

January 2002 MC 29,30
June 2001 NR 4

<u>Two trait crosses (dihybrid crosses)</u>

This type of cross involves examining the inheritance of two characteristics at the same time. Consequently there will be more gametes with different combinations of alleles that could be used for fertilization. The largest type of punnett square produced is the example where both parents are heterozygous for both characteristics (called a dihybrid). The example Mendel used was plant height and seed color.

1) The alleles for plant height are tall (T) and short (t), and for seed color yellow (Y) and green (y).

2) Parent cross : Tall yellow seed plant X tall yellow seed plant (both parents are heterozygous)
TtYy X TtYy

3) Gametes produced from each parent are the same:
TY, Ty, tY, ty X TY, Ty, tY, ty

	TY	Ty	tY	ty
TY	TTYY	TTYy	TtYY	TtYy
Ty	TTYy	TTyy	TtYy	Ttyy
tY	TtYy	TtYy	ttYY	ttYy
ty	TtYy	Ttyy	ttYy	ttyy

4) Genotype ratio: not done when chart is this big
Phenotype ratio: always 9:3:3:1
9/16 (both dominant characteristics) tall and yellow seeds
3/16 (dominant, recessive) tall and green seeds
3/16 (recessive, dominant) short and yellow seeds
1/16 (recessive, recessive) short and green seeds

Two trait crosses do not always have to be dihybrid, where both parents are heterozygous. One parent can be dihybrid and the other h. dominant for both characteristics, or one parent can be h. recessive for both characteristics and the other hybrid for one and homozygous for the other. There are many different combinations. Consequently, the number of different gametes produced in each case can be different and the punnett square shape and size (number of square to fill in) be different as well (not always 4 x 4).
(June 2002: MC 32)

<u>Variations of the two trait cross: Polygenic Inheritance</u> pg. 607

a) epistatic interaction
This involves genes that prevent the expression of other genes. Coat color in dogs is an example.
1) Alleles: B=black, b=brown, a separate gene on a separate chromosome also influences coat color, W=prevents color formation results in white, w=allows color formation.
2) Parent cross: White dog X Black dog
WwBb X wwBb
3) gametes from one parent WB, Wb, wB, wb, and from the other parent wB, and wb

	wB	wb
WB	WwBB	WwBb
.wB	wwBB	.wwBb
Wb	WwBb	Wwbb
.wb	.wwBb	wwbb

4) Phenotypes : 4/8 White, 3/8 black, 1/8 brown

b) complementary interaction

This occurs when two different genotypes interact to produce a phenotype that neither is capable of producing by itself (like incomplete dominance). One of the best examples of complementary interaction can be seen in the combs of chickens.

1) Alleles: Rose comb=R, P on a different chromosome produce Pea comb, when the R and P alleles are both present they produce walnut comb, the absence of both R and P (only recessive, r and p, homozygous for both r and p) produces single comb.

2) Parent cross: rose comb X pea comb (both parents homozygous for rose and pea)

RRpp X rrPP

3)

	rP
Rp	RrPp

4) Produces 100% RrPp which is walnut comb

If these F_1 individuals are crossed they produce the following:

1) use the same alleles as in the parent cross

2) Parent cross: Walnut comb X Walnut comb

RrPp X RrPp

3)

	RP	Rp	rP	rp
RP	RRPP	RRPp	RrPP	RrPp
Rp	RRPp	RRpp	RrPp	Rrpp
rP	RrPP	RrPp	rrPP	rrPp
rp	RrPp	Rrpp	rrPp	.rrpp

4) Phenotypes: 9/16 walnut (RRPP, RRPp, RrPP, or RrPp)
3/16 rose (RRpp or Rrpp)
3/16 pea (rrPP or rrPp)
1/16 single (rrpp)

• ***explaining the influence of crossing over on the assortment of genes on the same chromosome; e.g., gene linkage*** pp.599-602

(Aug 2006: MC 10)

I) Recombinant genes

Crossing over in meiosis results in a different combination of genes in one or both of the parent gametes, compared to the gametes if crossing over did not occur. This illustrates that the same genes are found on the same chromosome in all people. Genes carried on the same chromosome are called linked genes. By examining the results of crosses of linked genes we can determine the sequence the genes are in on a chromosome. This sequence is called a chromosome map.

If we use the characteristics color and seed shape of pea plants we can illustrate the effects of crossing over on the expected phenotypes from a cross. The alleles we will use are Y=yellow, y=green, R=round seed, r=wrinkled seed. We will do three crosses to illustrate what happens when there is no crossing over (example 1), when there are linked genes (example two), and when there are linked genes that cross over.

Example one: Normal two trait(gene) cross.
1) Y=yellow, y=green, R=round seed, r=wrinkled seed.
2) Parent cross: Yellow round X Yellow round (both are heterozygous)
YyRr X YyRr
3) Gametes produced: each parent produces 4 possible gametes YR, Yr, yR, yr. Each alleles is carried on a separate chromosome.
4)Phenotypes: F_1: 9/16 Yellow round, 3/16 Yellow wrinkled, 3/16 green round, 1/16 green wrinkled (this is the standard outcome for a dihybrid cross)

Example two: Two trait cross with linked genes, Alleles Y and R are on one chromosome of the pair and y and r are on the other chromosome of the pair.

2) Parent cross: Yellow round X Yellow round (both are still heterozygous)
YyRr X YyRr
3) Gametes produced: Each parent will only produce 2 different gametes because there are only two chromosomes that carry the 4 different alleles. They are:YR and yr

	YR	yr
YR	YYRR	YyRr
yr	YyRr	yyrr

4) Phenotypes: ¾ yellow round, ¼ green wrinkled. This illustrates that each alleles could not have been on a separate chromosome otherwise we would see the standard 9:3:3:1 ratio as in example one.

Example three: Two trait cross with linked genes and crossing over. This is the same as example two except that in one of the parents the homologous chromosomes switch genes during gamete formation (metaphase I of meiosis) resulting in a different combination in the gametes.
2) Parent cross: Yellow round X Yellow round (both are still heterozygous)
YyRr X YyRr
3) Gametes produced: from one parent: YR and yr, but from the other: Yr and yR

	YR	yr
Yr	YYRr	Yyrr
yR	YyRR	yyRr

4) Phenotypes: ½ yellow round, ¼ yellow wrinkled, ¼ green round. Notice there are no green wrinkled. The ratio produced here and the lack of green wrinkled from a dihybrid cross indicated linked genes and crossing over occurring. The unexpected phenotypes produced from this cross, yellow wrinkled and green round, (as compared to example two of just linked genes) are called recombinants because they formed as a result of a recombination of genes, by crossing over, during gamete formation.
(June 2002: MC 33)
Chromosome mapping
The number of recombinant individuals produced in a cross, divided by the total offspring produced by the cross is described as the crossover frequency for these genes. The higher the crossover frequency the farther the genes are apart from each other on the chromosome. The location of a specific gene on a chromosome is called its locus. Genes that are farther apart will have a greater chance of having crossing over occur between them than genes that are right next to each other. In other words, crossing over will occur more often between two gene that are at opposite ends of the same chromosome than genes that are right next to each other. The crossover frequency can be translated directly into a map distance that measures how far the genes are apart from each other. A frequency of 5% means a map distance of 5 map units (whatever that would be in distance is irrelevant here). From a table of data that lists crossover frequencies between several genes we can map the genes in a sequence on the chromosome.

Example

Genes	W	X	Y	Z
W	-	5	7	8
X	5	-	2	3
Y	7	2	-	1
Z	8	3	1	-

The sequence would map out as: W—5—X—2—Y—1—Z

January 2001 MC 31
June 2001 NR5, MC 31

• ***explaining the significance of sex chromosomes compared to autosomes, as investigated by Morgan.***
(Aug 2006: MC 11) pp.600-604

Thomas Hunt Morgan: added evidence from fruit flies to support the chromosome theory of inheritance. This stated that genes control all our traits and that genes are carried on chromosomes, pairs of chromosomes separate during meiosis, and that the pairs line up independently of each other during meiosis. The genes on one chromosome are all linked together. Sex is determined by two chromosomes.

I) Autosomes
Are the 22 pairs of chromosomes (44 in all) that determine most of our characteristics except sex. Genes that are carried on these chromosomes are called autosomal, they can be autosomal dominant (trait named after the dominant condition) or autosomal recessive (trait named after the recessive condition), autosomal codominant , or autosomal incomplete dominant. These are called the "modes of inheritance"

II) Sex chromosomes
These are the one pair of chromosomes that carry the genes that determine if we will be male or female. These where first identified by Thomas Morgan. He labeled the two chromosomes X and Y. Males receive and X and a Y chromosome, females receive two X chromosomes.

III) Sex linked crosses
Morgan found that the X chromosome also carries other genes that they Y chromosome did not carry, such as blood clotting factors and color vision. Some of these characteristics have dominant alleles that determine the 'normal' development of that characteristic, but also have recessive alleles that, if expressed, result in incomplete development, or improper functioning, of that characteristic. Since these genes are only carried on the X chromosome the recessive gene would always be expressed whenever a male receives it (since he only gets one X chromosome and the Y chromosome can not carry a gene to prevent its expression). In females they would not always express the recessive gene if they received it because the other X chromosome could carry the dominant gene which would be expressed instead. As a result these 'sex linked genes' or 'sex linked disorders' are seen more in males than females, but can occur in females. When doing sex linked crosses the alleles are expressed as superscripts only on the X chromosome.
Example a colorblind man marries a normal vision woman with no history of colorblindness

Alleles: XY= male XX = female normal vision = C colorblind=c

Parent cross: X^cY X X^CX^C

	X^c	Y
X^C	X^CX^c	X^CY
X^C	X^CX^c	X^CY

Phenotypes: 50% male normal
50% female carrier (they are heterozygous for vision but are still normal)
January 2001 MC 25, 24 June 2003: MC 7 June 2000 MC 23 June 2002: MC 29

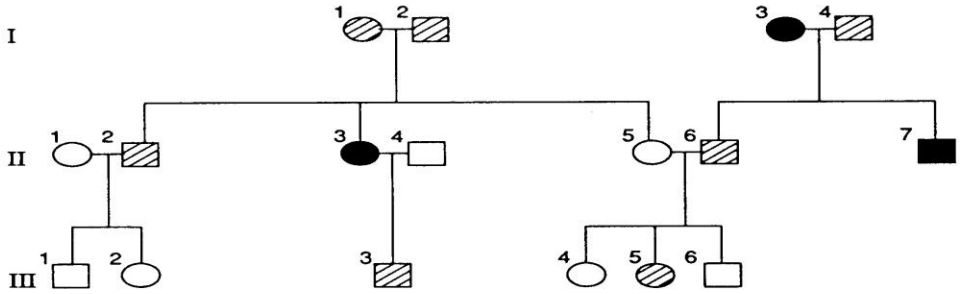
IV) Pedigree charts (refer to diagram 58) pp.610-615

Pedigree diagrams are drawn to illustrate the inheritance of a particular trait over several generations within a family. These diagrams can help determine whether a phenotype is controlled by a dominant, recessive, or sex-linked trait. For example, If both parents show a trait but some of their children do not, then the trait is controlled by an autosomal (not sex chromosome) dominant allele. If neither parent show the trait, but it appears in one or more of their children, then the trait is controlled by an autosomal recessive allele. If the trait appears primarily in males and it "skips a generation", it is probably a sex-linked recessive trait. Many of the traits examined using pedigree diagrams are hereditary disorders.

In a pedigree diagram, each generation is numbered using Roman numerals, with the oldest generation always number I. Each individual within each generation is numbered with an Arabic numeral, so that each individual is known by the combination of the generation and the individual numbers. E.g., III-4. The gender and genotype of the individuals are indicated by the following symbols:

O=female, □=male, if they are totally shaded in they express the disorder, half shaded means a known heterozygote for an autosomal recessive disorder, a dot in a circle is a known carrier of a X-linked (sex linked) recessive disorder. A carrier is an individual with a normal phenotype, but who has the gene in question and can pass it on to offspring (is heterozygous).

June 2001 MC 24,25 June 2002: MC 25,26,27,28 June 2003: MC 4



Pedigree of a family with some members afflicted with sickle-cell anemia

Pedigree Symbols

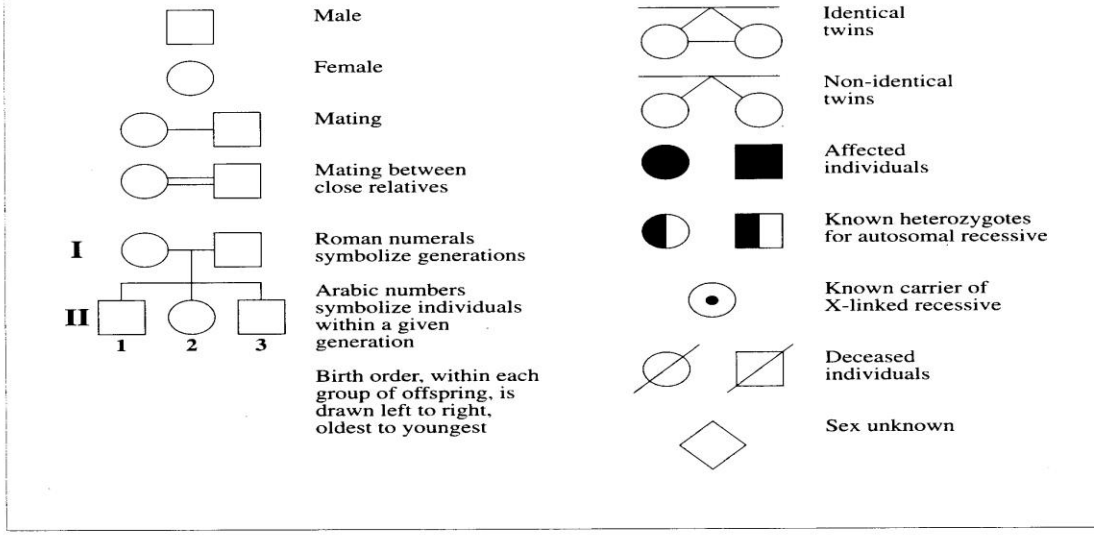


Diagram 58: Pedigree diagrams and notation for pedigrees

3. Classical genetics can be explained at a molecular level.

• genetic information in chromosomes is translated into protein structure; that the information may be manipulated; and that the manipulated information may be used to transform cells, by:

A • summarizing the historical events that led to the discovery of the structure of the DNA molecule, as described by Watson and Crick. pp.624-628

1) 1. James Watson and Francis Crick first identified DNA structure in 1953

B • describing, in general, how genetic information is contained in the sequence of bases in DNA molecules in chromosomes; how the DNA molecules replicate themselves; how the information is transcribed into sequences of bases in RNA molecules and is finally translated into sequences of amino acids in proteins pp.628-633

The structure of DNA

1) Chromosomes are composed of a long molecule of DNA and proteins that the DNA wraps around.
2) DNA is the abbreviation for deoxyribonucleic acid. DNA carries the instructions to put amino acids into sequences that make proteins.
3) DNA is subdivided into segments called genes.Chromosomes (DNA molecule) can carry several hundred to several thousand genes, depending on the size of the chromosome. Each gene codes for a specific protein (one gene-one enzyme hypothesis).
4) The gene in turn is composed of many units called nucleotides. The nucleotide is the basic building block of the DNA molecule.
5) One nucleotide is composed of three parts: a phosphate, a sugar (deoxyribose), and one of four different nitrogen bases (adenine-a, thymine-t, cytosine-c, and guanine-g) see diagram 59. The nucleotides can attach to each other end to end, from sugar to phosphate to sugar to phosphate forming the side of a ladder, while the nitrogen bases (which are attached to the sugar) can attach to other nitrogen bases (through the formation of hydrogen bonds), specifically a only with t, and c only with g (see diagram 60). When two nitrogen bases are paired together this is called a base pair. The base pairs form the steps of the ladder. The result is a ladder like structure that twists and spirals at the same time forming a structure called a double helix (see diagram 61). In all 46 human chromosomes there are 3 billion base pairs. The larger the chromosome the longer the DNA molecule and the more base pairs it has. Purines=A and G Pyrimidines =C and T. A gene is a sequence of nitrogen bases that tells the cell to make a specific protein.

January 2001 MC 35 June 2002: NR 6
January 2002 MC 25 June 2002: MC 35

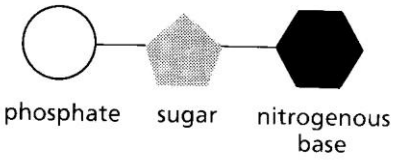


Diagram 59: The structure of the nucleotide

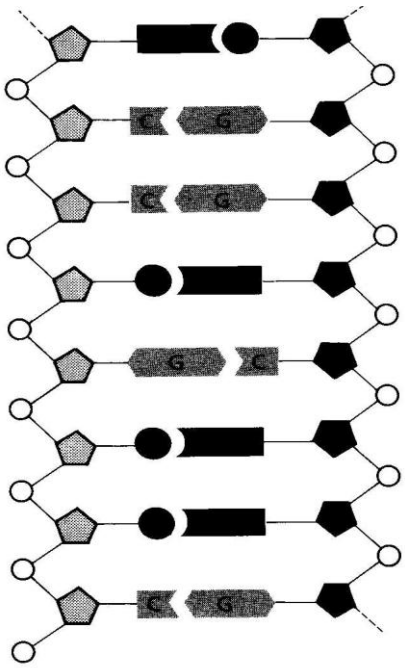


Diagram 60: The structure of DNA with nitrogen base pairing

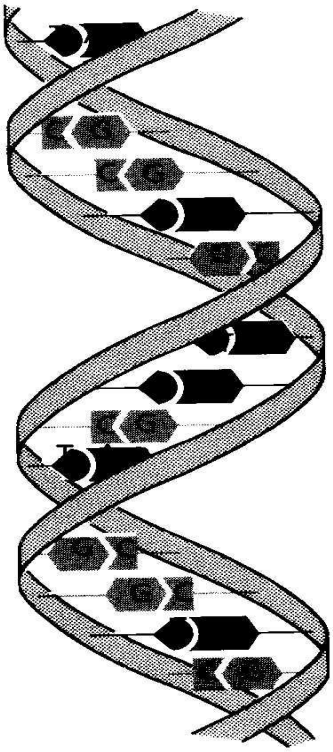


Diagram 61: The double helix structure of DNA

A) Genes and DNA

Genes are shorter (relatively) segments of the DNA molecule (chromosome) that code for the production of a specific protein. There are several categories of genes:

1) Introns-meaningless segments of the DNA. They code for no specific protein and appear to have no function (as of yet). About 95% of all DNA in humans
2) Exons-parts of the DNA that actually form the gene, examples: structural, regulator, oncogenes, transposons. Make up only about 5% of all DNA in humans
3) Structural genes- these are genes that direct the synthesis of proteins in individual cells. The proteins are used to build cell structures, or other important molecules ex. hormones, neurotransmitters, hair.
4) Regulator genes-control the production of repressor proteins, which switch off structural genes
5) Oncogenes-are genes that specifically cause cancer
6) Transposons-moveable genes-these are specific segments of DNA that can move along the chromosome (also called 'jumping genes')

B) DNA replication (see diagram 62)

(DNA synthesis of the cell cycle)—this occurs in mitosis and meiosis forming the sister chromatids. This is also called semiconservative replication because it conserves one half of the old DNA strand in each of the new DNA molecules formed. This occurs in two stages: 1. The DNA unzips between the nitrogen bases, breaking the hydrogen bonds. 2. New nitrogen bases (individual nucleotides, which come from the food we eat and are floating around inside the cell cytoplasm) are added to the exposed nitrogen bases on each half of the old DNA. The new strands that form on the old half strand are called complementary strands. The nucleotides are glued together by an enzyme called DNA polymerase, a form of ligase (discussed later).

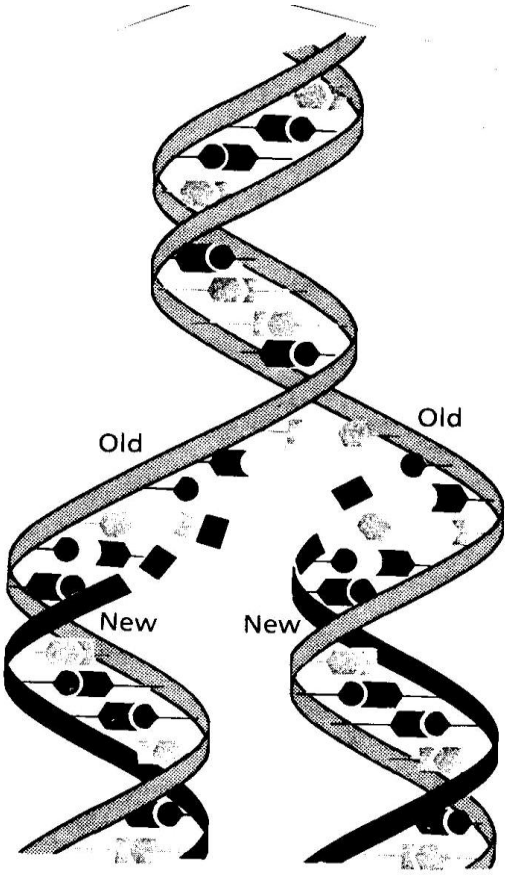


Diagram 62: DNA replication, or semiconservative replication

C) Protein Synthesis pp.636-642

Each gene is composed of hundreds or even thousands of base pairs. It is the sequence of a,c,t, and g along the DNA molecule that codes for the production of a specific protein by specifying which amino acids to use, in what order, and how many to use. This process, called protein synthesis, occurs in two sequences: transcription and translation.

Transcription (see diagram 63)

This is a process of copying the nitrogen base sequence in the DNA and bringing it to the ribosome where translation occurs. There is a special type of nucleic acid built to perform this function called messenger RNA, or mRNA.

RNA	DNA
Single Helix	Double Helix
Ribose	Deoxyribose
Adenine/Uracil	Adenine/Thymine

There are three steps in transcription:

1) the DNA of a specific gene unzips between the base pairs, the hydrogen bonds that hold the nitrogen bases together are broken.
2) mRNA nucleotides attach (base pair) to the exposed nitrogen bases of the DNA molecule.
3) The mRNA nucleotides join together forming a single strand that detaches, leaves the nucleus, and moves to the ribosome.

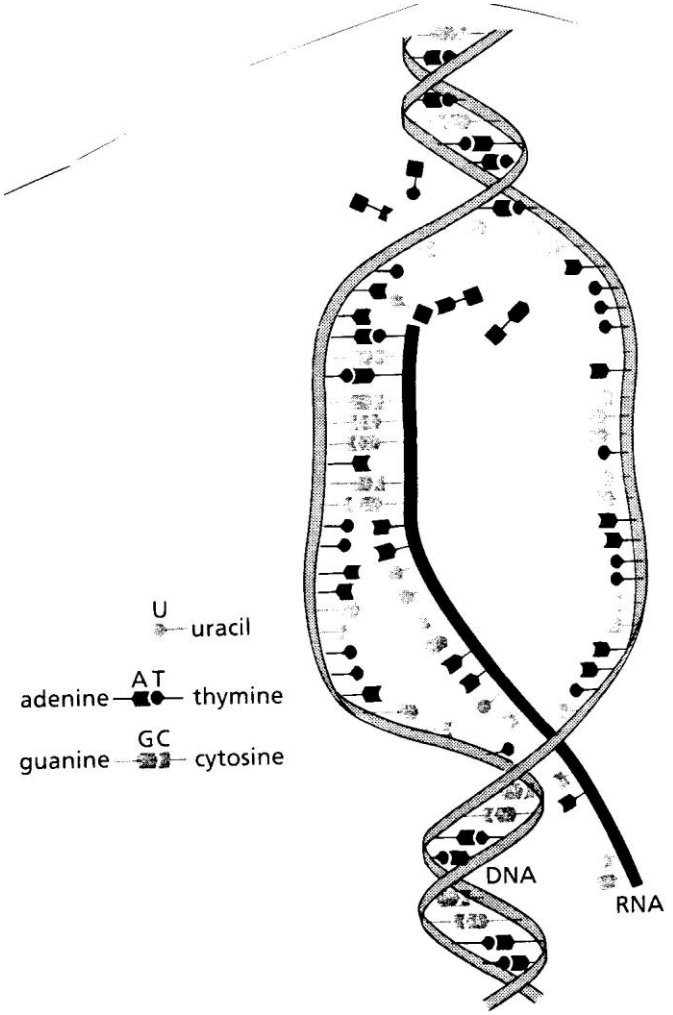


Diagram 63: Transcription of DNA into mRNA

Translation (see diagram 64)
This is a process of translating the mRNA nitrogen base sequence into a series of amino acids that will link together to form a protein. A set of three nitrogen bases on the mRNA will code for one amino acid. This set of three nitrogen bases is called a codon. There are only 20 different amino acids. If only one nitrogen base was used to code for amino acids then only 4 different amino acids could ever be selected (since there are only 4 different nitrogen bases in a mRNA). If two nitrogen bases were used to code for amino acids then only 16 different amino acids could ever be selected (since there are 16 different combinations of pairs from 4 different letters, ex ac, at, ag, aa, ct, cc, cg, etc.). With three letter combinations there are 64 possible combinations (codons). This is more than enough to allow the cell to select one of the 20 different amino acids and also include combinations for instructions to identify the start of a protein (called an initiator codon) and to signify that the protein is finished (a terminator codon).
This process also involves the use of another type of RNA called transfer RNA or tRNA. Transfer RNA picks up the different amino acids, found floating around inside the cell (they come from the food you eat), and brings them to the mRNA attached at the ribosome. The tRNA also has a set of three nitrogen bases, called an anticodon, that will match up to a codon on the mRNA strand putting the amino acid it holds in the proper spot.
Translation occurs in five steps:

1) mRNA strand attaches to the ribosome
2) tRNA pick up amino acids in the cell
3) tRNA with attached amino acids move to the mRNA. The tRNA anticodons match up and attach to mRNA codons
4) amino acids bond together to form a protein
5) mRNA and tRNA break apart with the mRNA returning to the nucleus and tRNA returing to the cytoplasm to pick up more amino acids. The protein will now be used by the cell or sent out of the cell for a specific function

January 1999 MC 39
January 2002 MC 26

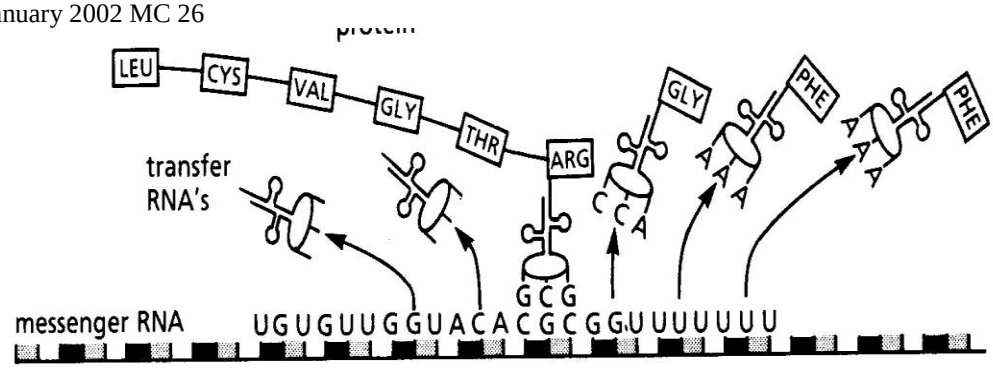


Diagram 64: Translation of mRNA into a protein using tRNA

• ***explaining, in general, how restriction enzymes and ligases may cut DNA molecules into smaller fragments and reassemble them with new sequences of bases*** pp.647-651

Restriction enzymes- are enzymes that cut DNA at specific sites (nitrogen base sequences)
Ligase-are enzymes that glue DNA nucleotides together at the nitrogen bases
DNA polymerase- joins the phosphates to the sugars to form the sides of the DNA ladder
Recombinant DNA-the combining of DNA from one species into chromosomes of another species

January 200 MC 38

• ***explaining, in general, how cells may be transformed by inserting new DNA sequences into their genomes*** pp.647-661

Human Genome project

A worldwide research project to identify all the nitrogen base sequences for all the genes of the human It was announced completed to the media on June 26, 2000. It began in the early 1980's. The human genome has just over 3 billion base pairs. There are about 30,000 different genes. If you took all the chromosomes from one cell and stretched out the DNA and joined them end to end it would be about 2 meters long. All the DNA in your body (from all cells that have a nucleus) would reach to the Sun and back 600 times. Only about 5% of our DNA are functional genes. In between the genes, there are long stings of base pairs in seemingly random patterns. These in between bits are called "junk DNA". It is still uncertain is junk DNA has any function.

Genetic engineering and Biotechnology

Biotechnology is the application of knowledge of DNA to the production of materials for human use. The first breakthrough was the discovery of a group of enzymes called restriction endonucleases (enzymes). These enzymes have made it possible to read the precise order of the nucleotides in DNA and also to cut and join different fragments of DNA from similar or totally different sources (species). Much of this research is done with bacteria and viruses. The bacteria are often mutant strains of E.coli (normal E.coli are found in our colon) and are incapable of survival outside the lab. Viruses consist largely of DNA. They function and reproduce themselves by injecting their DNA into a cell. They can also be used in the lab to introduce DNA into a cell as the researcher requires.

Viruses, which attack bacteria cells, are called bacteriophages. Bacteriophages (viruses) and the DNA carrying the desired gene are mixed together, and a restriction enzyme is added. The result is that all the DNA fragments are cut at corresponding locations. DNA ligase and DNA polymerase can then be added to cause the fragments to rejoin. Where the cutting happens and where the different segments rejoin is all a matter of chance. Some will cut at the proper spots and join at the proper spots, but most will not resulting in mostly nonfunctional DNA segments of many different lengths. However, some of the bacteriophage DNA, a very small percentage, will now contain the desired DNA, called recombinant DNA (see diagram 65). The recombinant DNA viruses are allowed to infect E.coli bacteria, which are then cultured. Once again only a small percentage of bacteria will incorporate the viral DNA into its own DNA, but the bacteria that do show the desired characteristic (by producing products from the recombinant DNA) are isolated, and more are cultured. The bacteria can contain the gene for human insulin, growth hormone, and antibodies to disease for vaccines, clotting proteins, and many more important molecules. When the bacteria grow they will also produce these molecules which can be separated and refined from the culture.

(June 2002: MC 26,27)

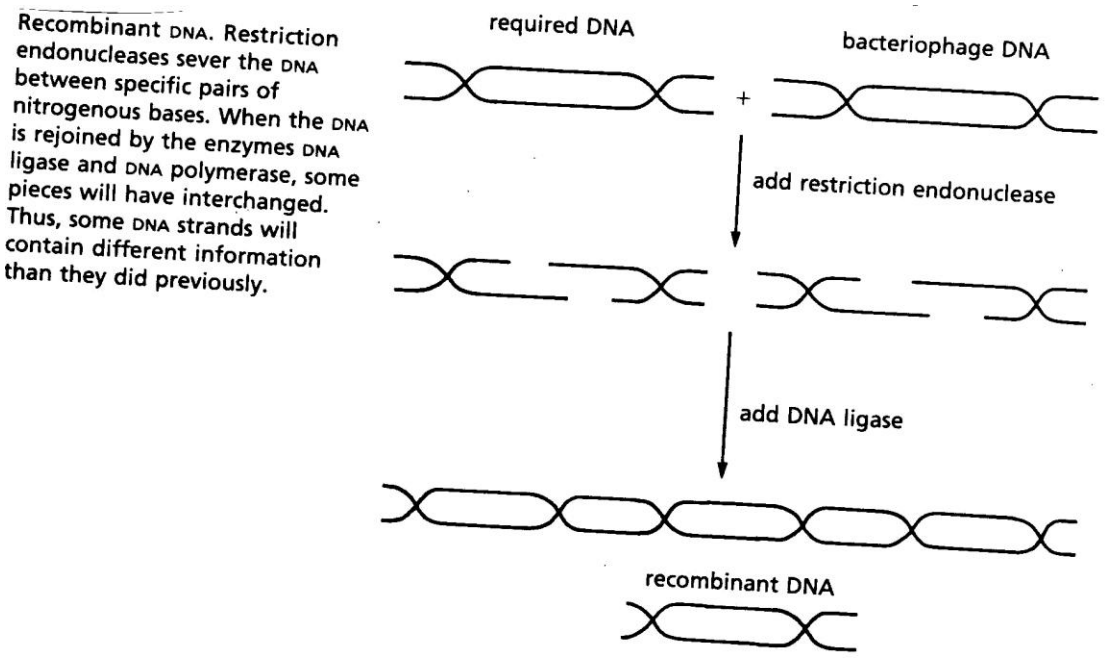


Diagram 65: One form of genetic engineering, the formation of recombinant DNA

• ***explaining how a random change (mutation) in the sequence of bases provides a source of genetic variability*** pp.643-646

Mutations

A permanent change to the genetic code (nitrogen base sequence) is called a mutation. DNA is a tough molecule that is resistant to damaging changes. DNA is well protected by a strong complement of proteins, a sugar-phosphate backbone, and a tight, double helix structure. The specific way that bases pair also helps to protect DNA from genetic damage. However, it can become damaged by radiation, chemicals, and viruses and in a variety of other ways. The damage is a change in the nitrogen base sequence. This in turn will result in a different mRNA sequence in transcription which may lead to a different amino acid produced during translation. (this is called Degeneracy; when more than one codon can produce the same amino acid) This change in amino acids may totally alter the shape and function of the protein. The new proteins may be harmful, nonfunctional, or beneficial. If it is beneficial it is a new adaptation for the species and could lead to microevolutionary changes in the population.

There are several categories of mutations:

1) Point mutations- a minor mutation where one nucleotide pair replaces another. This involves a base substitution, insertion or deletion. A substitution will result in only one amino acid changing when translation occurs.

Point mutation type	Explanation	Example
Base substitution	A foreign base replaces a normal base in each strand of a DNA sequence	ACGCCA becomes CCGCCA
Insertion	A base is added into the normal sequence of DNA	ACGCCA becomes AACGCCA
Deletion	A base is removed from the normal sequence of DNA	ACGCCA becomes …CGCCA

2) Frame shift mutation- a point form mutation in which a nucleotide pair is inserted or deleted causing the whole strand to be translated differently. Examples include insertion and deletion.
   Insertion: the mRNA code GAG/AAA/AAG/CGA would normally produce the amino acids glu/lys/lys/arg but if a G was added to the front of the mRNA the code would read GGA/GAA/AAA/GCG/A and would then produce the amino acids gly/glu/lys/ala.
3) Chain terminating mutation or nonsense mutation-a mutation resulting in a stop signal instead of a normal amino acid. The stop signals include UAA, UAG, UGA. This can result in a fragment of the protein being produced instead of the whole protein.
4) Silent mutations-a mutation which has no effect on the individual. Many point mutations have no effect on the cell because certain amino acids have more than one code.

• ***explaining how information in nucleic acids contained in the nucleus, mitochondria and chloroplasts gives evidence for the relationships among organisms of different species.*** pp.646-647

Types of DNA
DNA is found in the nucleus, mitochondria and chloroplasts. This suggests that both mitochondria and chloroplasts may have evolved independently before the first cells and later both organelles developed a relationship inside another cell. Over time this cell has refined itself into the modern cell that we see today. Mitochondrial DNA is inherited only from the mother. It can be compared to determine ancestry of organisms.

Protein Clock Theory- is a method using differences in types of amino acids of the same protein in different species to determine evolutionary ancestry. It states that the greater the difference in types of amino acids used to make the same protein (example hemoglobin in fish and hemoglobin in amphibians, or hemoglobin in humans and hemoglobin in horses) the further in the past the evolutionary ancestor of those organisms existed. Since proteins are made from the instructions in DNA and over time DNA changes in many ways, by many methods, and by many different agents the proteins will change over time. The greater the change between two proteins indicates the longer the time was that the two proteins diverged from each other, in other words—had a common ancestor.

In the same way amino acid sequences are compared to determine ancestry, DNA can be compared to do the same thing. For example human and chimpanzee DNA is over 99% the same sequences, while the DNA of chimpanzee and horses is much less similar. This indicates that chimpanzees are more closely related to humans than to horses, or we shared are more recent ancestor with chimpanzees than with horses. These differences are produced by mutations, both point form and chromosomal.

January 2002 MC 23, 37

UNIT 4
CHANGE IN POPULATIONS AND COMMUNITIES

1. Communities are made up of populations that consist of pools of genes from the individuals of a species.
- ***populations can be defined in terms of their gene pools, by extending from Biology 20, Unit 3, the nature of variation and adaptation in populations, and by:***

- ***describing the Hardy–Weinberg principle and explaining its importance to population gene pool stability and the significance of nonequilibrium values; e.g., evolution of a population*** pp.678-687

A gene pool is the sum of all the alleles for a characteristic in a population. The Hardy Weinberg principle states that if all factors that could influence the population remain constant the frequency of a gene in the gene pool will also remain constant, no changes will occur in the population. A gene/allele frequency refers to the numbers of a specific allele out of the total of that gene (both alleles) in the population. This principle allows the prediction of changes in the population (microevolutionary changes). We can count the frequency of the alleles for a gene in a population at one date and return to the population years later, recount and recalculate the allele frequencies, and determine if the population has changed, in what direction, possibly the factors making the change happen, and predict future change.
The following formula allows the determination of the frequencies of genotypes for a specific gene (with only 2 alleles p and q, where p is the dominant allele and q is the recessive allele) in the population: $p^2 + 2pq + q^2 = 1$. Where p^2 is the frequency of the homozygous dominant genotype, 2pq is the frequency of the heterozygous genotype, and q^2 is the frequency of the homozygous recessive genotype. All three terms add up to 100% of the population so the equation always equals 1 (100%). When the values for these three terms stay the same over a period of time they are described as being 'in equilibrium'. When the values change over a period of time (microevolutionary change) they are described as 'nonequilibrium values'.

In summary:

p^2 = homozygous dominant genotype ex. AA
2pq = heterozygous genotype ex. Aa
q^2= homozygous recessive genotype ex. Aa
$p^2 + 2pq + q^2$ = 100% of the population, or the sum of all the genotypes percentages in the population

January 2001 MC 29-34 June 2002: MC 40
January 2002 MC 30-36
June 2000 MC 27
January 1999 NR 5, 6
June 2001 MC 21-29, NR 4, WR 1

- ***describing the conditions that cause the gene pool diversity to change; e.g., random genetic drift, gene migration, differential reproduction*** pg.681

(Aug 2006: MC 14)
The factors that must remain constant are: large population, random mating, no mutations, no migration, and all alleles are equally viable-have the same reproductive success. If these factors are not constant the frequency of the allele in the population will change.

1. Large populations ensure that only the laws of probability apply, that it is highly unlikely that chance alone will alter the frequencies of the alleles. Small populations result in genetic drift—where the frequencies change as a result of chance. Two examples of this are the Founder Effect and Population Bottleneck.
2. Random mating ensures that there is equal chance for all alleles to combine at fertilization. Nonrandom mating produces a preference for a specific phenotype and thus can favor a specific genotype increasing its frequency in the population above the equilibrium value (frequency).

3. No mutation ensures no new alleles are produced by physical means to the chromosomes (DNA). If mutations happen creating new alleles that would alter the frequencies the gene pool.
4. Migration involves both new members entering or leaving the population. If this happens the numbers of each of the two alleles will change corresponding to the new members that enter or leave. If there is no migration to or from the population, and all 5 other factors listed here are in effect, then the allele frequencies and corresponding phenotype frequencies will be maintained as the population grows generation after generation. This effect is called the "Founder Effect", the population phenotypes reflects the initial 'founding' population.
5. All the alleles equally viable means there is no difference in reproductive success of the offspring with the different alleles. The offspring of all possible matings are equally likely to survive and to reproduce in the next generation. If one phenotype in favored then those alleles will occur more frequently in the next generation and so forth generation after generation. This would change the allele and genotype frequencies in the population over time which is defined as a microevolutionary change.

January 1999 MC 34, NR 5, 6
January 2000 MC 41, 42

• ***applying, quantitatively, the Hardy–Weinberg principle to observed and published data*** pp.681-683

Examples:
1. If the frequency of the dominant allele is 70% (the frequency of the recessive allele must be 30%--these also must add up to 100%, or p=0.7 and q=0.3) the frequency of the genotypes and phenotypes in the population is as follows:

$p^2 = .7^2 = .49 = 49\%$ $2pq = 2 \times .7 \times .3 = .42 = 42\%$ $q^2 = .3^2 = .09 = 9\%$

$p^2 + 2pq + q^2 = 1$ $49\% + 42\% + 9\% = 100\%$

2. If the frequency of the homozygous recessive phenotype in a population is 40 in 1000 the frequency of the alleles and other phenotypes and three genotypes is calculated as follows:
40/1000 = 4% = homozygous recessive genotype = q^2
$q = \sqrt{q^2} = \sqrt{.04} = .2$ since p + q must equal 1, if q is .2 then p is .8
$p^2 = .8^2 = .64 = 64\%$ $2pq = 2 \times .8 \times .2 = .32 = 32\%$ $q^2 = .2^2 = .04 = 4\%$
$p^2 + 2pq + q^2 = 1$ $64\% + 32\% + 4\% = 100$
To find the numbers of each genotype in the population (of 1000):
Homozygous dominant = $p^2 = 64\% \times 1000 = 640$
Heterozygous = $2pq = 32\% \times 1000 = 320$
Homozygous recessive = $q^2 = 4\% \times 1000 = 40$

To find the numbers of each phenotype:
dominant phenotype = 640 + 320 = 960
recessive phenotype = 40

January 2001 MC 29 June 2002: MC 31 June 2003 MC 6

• ***describing the molecular basis and significance of gene pool change over time; i.e., mutations.*** pp.689-696

The molecular basis for gene pool change over time centers on mutations. Specifically changes in the nitrogen base sequence in the DNA as discussed in unit three concept three. If mutations, of any form, occur these can cause a different allele to be produced. This would alter the numbers and frequency of all the other alleles in the population. Therefore the initial equilibrium (or frequencies of alleles and corresponding genotypes), before the mutation occurred, would not be maintained.

The significance of gene pool change over time is that it allows populations/species to survive. The changes individuals receive in their lifetimes do not get passed on to their offspring. Only mutations that affect the

genes in the gametes get passed on to the individuals offspring. The populations gene pool changes over time according to Hardy weinberg variables.
If a populations gene pool does not change while the surrounding environment, their habitat, does they must either move to another area similar to the habitat they have genes/traits for (called habitat tracking) or they will eventually die off (extinction). They will not have traits that allow them to survive in the new habitat and consequently not reproduce as much as possibly other organisms. They will be outcompeted in this new area (natural selection) and as a population or even species become extinct if no other new habitat similar to the old one can be found. With changes to the gene pool, by mutation, small populations, nonrandom mating, unequal viability, and migration, new genes can enter the population giving the species a new trait in a changing environment. The new trait may allow the species to survive allowing some of its members to survive in a new habitat. This is classified as microevolution, or changes in the gene pool that do not directly cause speciation (a new species formed).
June 2001 MC 19, 20 January 2001 MC 43 June 1999 MC 42

2. Individuals of populations interact with each other and members of other populations.
• interactions occur among members of the same population of a species as well as among members of populations of different species, by:

• describing the basis of symbiotic relationships, i.e., commensalism, mutualism, parasitism, and interspecific and intraspecific competition and their influences on population changes
(Aug 2006: MC 12) pp.717-725

Populations: Members of the same species in a defined area at a defined time
Species: Individuals that can reproduce to produce fertile offspring
Ecological niche is an organisms profession, role, trophic level or feeding level, in the ecosystem. It is the total environment and way of life of all the members of a particular species in the ecosystem.
Producer: capture energy and produce carbohydrates. Usually plants, usually photosynthetic
Consumer: eat plants or animals to obtain their nutrients and energy. Usually animals
Decomposer: consumer any organic material to obtain their energy, converting the material into compounds usable by the producers. Ex. bacteria, worms
Scavenger: eats any type of plant of animal remains. Ex. crow, magpie, coyote
Saprotroph: digest their food (usually dead plant material) outside their body. Ex. mushrooms, fungi.
Herbivore: Animals that eat plants
Omnivore: Animals that eat plants or animals
Carnivore: Animals that eat other animals
Autotroph: Make their own food, usually by photosynthesis (plants)
Heterotroph: Obtain their food from an external source (animals)
Biotic: the living factors in the environment, other organisms
Abiotic: the nonliving factors in the environment, wind, temperature, humidity, precipitation
Habitat: the environment in which an organism survives.
Geographic range: The total area, extent of locations of habitat, where and organism may live naturally .
Individuals of a population are constantly interacting with each other and with individuals of other populations of the same or different species.

Interactions in populations may be a)cooperative or b)competitive and are classified into five major categories: Commensalism, mutualism, parasitism, detritivory, and predation.

a)Symbiotic relationships (mutualism, commensalism, parasitism)
Symbiotic relations (symbiosis) are cooperative relations that occur when two or more species live closely together (coexist) over a long period of time. Species that do coexist for a period of time in proximity to each other have one or more different factors as part of their niches. The relationship may improve the chances of survival for one or both species, or harm one of the species.

Relationship	definition	interaction	Symbol
Commensalism	Two organisms of different species that live together and share food, shelter, support.	The commensal benefits The host is not harmed	(+,0)
Mutualism	Two organisms of different species that coexist and benefit from each other	Mutualist benefits Other mutualist benefits	(+,+)
Parasitism	When one species (parasite) lives on or in another (host) using the host as a food source or other purposes	Parasite benefits Host harmed Or sometimes not harmed	(+,-) (+,0)

Detritivory is not a symbiotic relationship. This occurs when one organism consume the dead organic remains of another organism (detritus)

b)Competitive interactions
Gause's competitive exclusion principle: states that two species can not occupy the same niche at the same time without one eliminating the other.

There are two basic categories of competition: interspecific and intraspecific:
Interspecific competition refers to competition between different species for a limited resource (food). This interaction will reduce or limit the size of a population and select those members that have the best traits for survival in each species (natural selection).
Intraspecific competition refers to competition between members of the same population for a limited resource (food, shelter, mates). This also will reduce population size and select those members of the population that have the best traits for survival (natural selection)

January 1999 MC 46, NR 8, June 1999 MC 44, 47, January 2001 MC 42, 48, June 2001 MC 45-48, NR 8
June 2002: MC 39, 46 June 2003: NR

• ***describing the relationships between predator and prey species and their influence on population changes; and explaining the role of defence mechanisms in predation; e.g., mimicry, protective colouration*** pp.719-723

Predation
Predation involves an organism that hunts and kills another organism called the prey. Predation is not a symbiotic relationship. The predator benefits while the prey is harmed. Obviously the predator, if the only factor, will cause the prey population to decline, but it is not in the best interest of the predator population that over predation deplete the prey population to the point where it no longer sustains the predator. At this point prey populations or lack thereof cause predator populations to migrate, get weak and become more susceptible to disease, or migrate to new areas with more food. Prey have also evolved various defense mechanism to predation. These include mimicry, protective coloration, freeze, flight or fight, tricking predators, group behaviors, or chemical defenses. Mimicry is a form of camouflage that involves developing a similar color pattern, shape, or behavior that has provided another organism with some survival advantage. Protective coloration includes the ability of a prey to blend into its environment by camouflaging itself. Mimicry of color is a form of this. Some organisms, however, use warning coloration to 'tell' other organisms not to touch them because they are dangerous. Tricking predators can involve the use of loud noises, changing body size, expelling body parts, pretending to be injured, to distract or frighten the predator. The freeze response involves the alerted prey immediately stopping so as not to draw attention. This is effective if the prey has good camouflage. Fight response works well against a predator that is not well equipped to fight itself (cheetah), but is often a last resort often resulting is damage to the prey. Flight refers to the prey running from the predator.

January 2002 MC 43, 45 June 2002: MC 27
June 2000 MC 44, 46
January 2000 MC 43,44

• ***explaining how mixtures of populations that define communities may change over time or remain as a climax community; e.g., primary succession, secondary succession.*** Pp.725-728

Succession
The interactions between organisms and the environment follow a pattern of moving from simple to complex interactions over time. This directional change in complexity is referred to as succession. Community changes produced by succession lead to increasingly stable biological environments. They usually start with a pioneer community and finish with a climax community. Pioneer plants eventually form a pioneer community. Pioneer communities have a low biomass with vast amounts of solar energy uncaptured and wasted. As succession progresses biodiversity increases because of the diversity of vegetation and food available, with a corresponding increase in biomass. Once the final stage is reached, due to a lack of different types of plants, the biodiversity decreases but biomass remains high. A complex community that finally becomes balanced is referred to as a climax community. Climax communities have a high biomass, a narrower variety of species (lower biodiversity), and heterotrophic plant species (plants that live off dead plant life, saprotrophs). Climax communities tend to be stable with complex food webs. The intermediate stages that lead up to the climax community are called the seral communities. There may be several seral communities before the climax community is established.

Primary succession
The process of creating a complex community from an environment that never supported life is referred to as primary succession. In certain areas such as mountain slopes, glacier areas and volcanic slopes, a biological community does not exist. Certain sturdy life forms may move into the areas where no life exists and make the conditions right to support life. Areas with no life generally have no soil, and poor water conditions. The first organisms that are able to live in this area have the special ability to prepare a life-supporting environment from abiotic factors. Algae, lichens, and moss are sturdy plants that develop or prepare the way for more complex life forms. Their ability to move into a new environment that normally does not support life earns them the title of pioneer species After a long time of this existence, enough soil, water and organic material are added to the soil to make it more accessible to other plants (seral communities/stages) which then begin to grow (by windblown seeds, or other methods).

Secondary succession
The gradual changes that reclaim land or water that once supported life is called secondary succession. This type of succession involves the rebuilding of a certain area that may have at one time supported a well-developed and stable community. Secondary succession implies that good soil already exists in the damaged area.

January 1999 MC 4 June 2003: MC 10
January 2002 MC 44

3. Population change over time can be expressed in quantitative terms.
• ***populations grow in characteristic ways, and that the changes in population growth can be quantified, by extending from Biology 20, Unit 3, variations within populations, and by:***

• ***describing and explaining, quantitatively, factors that influence population growth; i.e., mortality, natality, immigration, emigration*** pp.704-714
June 2002: NR 7, Aug 2006: NR 4

Population: a group of individuals of the same species that occupy a defined space at a specific time
Natality: the birth rate of a population
Mortality: the death rate of a population
Immigration: the movement of new individuals into a population from another location

Emigration: the movement of members of a population out of the population to a new location
Closed populations: A population that does not allow immigration or emigration
Open population: A population that allows all four of the primary factors.

These are the four primary factors that influence the size of a population. However, many other abiotic and biotic factors in turn can influence these four. Natality, mortality, immigration and emmigration are influenced by gestation period, litter size, mate availability, gender ratio, food supply, density, availability of shelter, and water supply, to name a few. Many of these factors can interact together to produce other influences like increased susceptibility to disease, predation, or parasites

Four equations commonly used in population calculations are as follows.

1) Density = $\frac{\text{numbers}}{\text{area (length x width)}}$ $D = \frac{N}{A}$

2) Rate of change in density = $\frac{\text{change in density}}{\text{Change in time}}$ rate of density change = $\frac{\triangle D}{\triangle t}$

Any change is always calculated as the final number subtract the initial number, for time, density, or numbers
A negative value for rate of density change means the population is declining while a positive value means the population is increasing.

3) An equation that is used to calculate the per captia growth rate (cgr) of a population is:
$\frac{\text{(natality + immigration) - (mortality + emmigration)}}{\text{initial population size}}$ or cgr = $\frac{\triangle N}{N}$

4) The growth of a population can be calculated as follows. Start with a population of 1000, and 10% growth per year for 4 years.

Year	N (N + change in N)	change in N
1	1000	100
2	1100	110
3	1210	121
4	1331	133

After 4 years there would be 1464 organisms.

5) Another way of calculating this is with the exponential growth formula, or the compound interest formula.

Final population size = initial population size x (1. Put the population growth rate here)^{yeats}

Using the same example above:
Final population size = 1000 x $(1.10)^4$ = 1464.1 or 1464 organisms
January 1999 MC 48, NR 7
January 2001 Mc 41
June 2001 MC 47, NR 7
June 2000 MC 45, 47
June 2003 NR 3

• ***describing the growth of populations in terms of the mathematical relationship among carrying capacity, biotic potential and the number of individuals in the population*** pp.709-712

June 2002: MC 47,48, NR 8, Aug 2006: MC 13

Carrying capacity: is the number of individuals of a particular population that the environment can support under a particular set of conditions.
Biotic potential: is the fastest possible rate of population increase, given optimum conditions. Several factors increase biotic potential: sexual maturity age, litter size, length of gestation, length of reproductive life, capacity for survival
Environmental Resistance: is the biotic and abiotic factors in the environment that slow population growth.

January 1999 MC 43
January 2001 MC 40

• ***explaining, quantitatively, the behaviour of populations, using different growth patterns; i.e., r- and K-strategies, J and S curves*** pp.712-713

Nelson Biology 582-594
Population Growth Curves
The two basic growth patterns are described as a J shaped growth curve and an S shaped growth curve.

J shaped growth curves:
J shaped growth curves result when there is unrestricted growth in a population (see diagrams 66). This can only occur when there is unlimited space, resources, mates, etc. when the full biotic potential is reached. In nature this never happens. It may begin to happen when a new population inhabits a new habitat but soon biotic or abiotic factors in the environment slow the growth, limiting the size of the population and producing an S shaped growth curve. J shaped growth curves are named after the steep growth phase which will be defined in S shaped growth curves, next. In closed populations the J shaped growth curve ends in a death phase due to lack of food or disease.

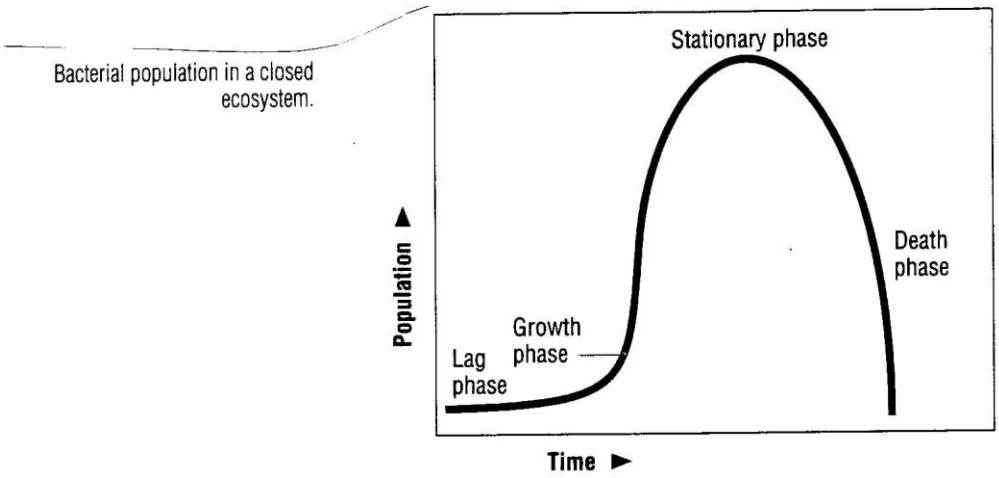


Diagram 66: J shaped growth curve in a closed population

S shaped growth curves:
Are produced when population growth is limited by environmental resistance. The upper limit to the size of the population is called its carrying capacity, as defined earlier. This limit is set by the biotic and abiotic factors in the environment, or environmental resistance. This is referred to as the Law of the Minimum, or the Law of Tolerance. If resources fall below the minimum to sustain a population the population will

begin to decline. The abundance or distribution of an organism can be controlled by factors exceeding the maximum or minimum levels of tolerance for that organism. In other words, each species has a tolerance for change in their environment that involves not only limited resources but also excesses of resources. Drastic changes that greatly limit or enhance certain resources can harm a population. The more tolerant a species is to the highs and lows of available resources, the more likely the species is to survive. Environmental resistance factors are the same as those that influence the four primary growth factors

Normal population growth demonstrates a sigmoid or s-growth curve (see diagram 67). The growth starts slowly, then speeds ups, and as it reaches its carrying capacity is slows down and levels off. This type of curve is characterized by 4 distinct phases:

1) Lag phase. This is the initial slow growth that occurs when the population or organism is adjusting to the new habitat, finding food, water, mates, shelter.
2) Growth phase. This is the time of rapid (exponential) growth. During this time the population more than enough resources to support the rapid growth and there is little environmental resistance. This is the boom period for the population.
3) Plateau or stationary phase. This is the period of leveling off of the growth. During this time environmental resistance slows the growth rate. In many populations the environmental resistance falls behind the population size and the population overshoots the carrying capacity.
4) Death phase. This the period when the population declines either a small amount if it has not surpasses the carrying capacity by much and done little damage to the environment or produced small amounts of disease, or it declines a lot due to massive starvation, disease, migration as a result of damage to the environment, lack or food or mates, etc. by the overpopulation.

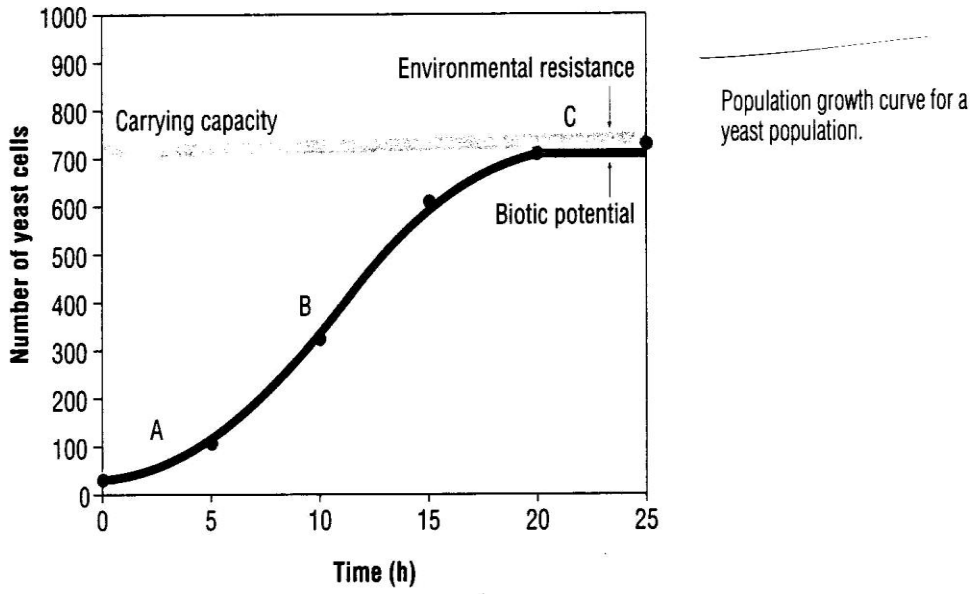


Diagram 67: S shaped growth curve

Population Growth Strategies: Reproductive Strategies
These include the strategies, behaviors, and adaptations members of a population use to ensure survival of their offspring and growth of the population. There are two extremes in population growth.

K strategists
K strategy populations are stable and live in stable and predictable habitats. They reach a mature age (live longer), have larger body sizes, longer parental care of offspring, longer gestation periods, smaller litter sizes, and later ages of reproduction. They usually are slow breeding populations that are able to stabilize at a carrying capacity. Examples include elephant, whales, and humans

r-strategists

The other extreme is a fast growing population with a rapid breeding rate and an unpredictable rapidly changing habitat. They can often overshoot the carrying capacity. The individuals in these populations have a low maturity age (do not live long), have small body sizes, require little or no parental care, produce many offspring during each breeding, have short gestation periods, and reproduce early and often. The populations tend follow a crash/death phase after they overshoot the carrying capacity. Examples include fish, flies, mice, and turtles.

Growth Strategy Continuum

K strategy----------r strategy

Elephants, whales, humans rabbits, mice turtles fish,insects

January 2002 MC 8
January 2000 MC 45, 47
June 2000 MC 35, 42, 43
June 1999 MC 42, 48
January 1999 MC 44
January 2001 MC 44-46
June 2002 MC 43